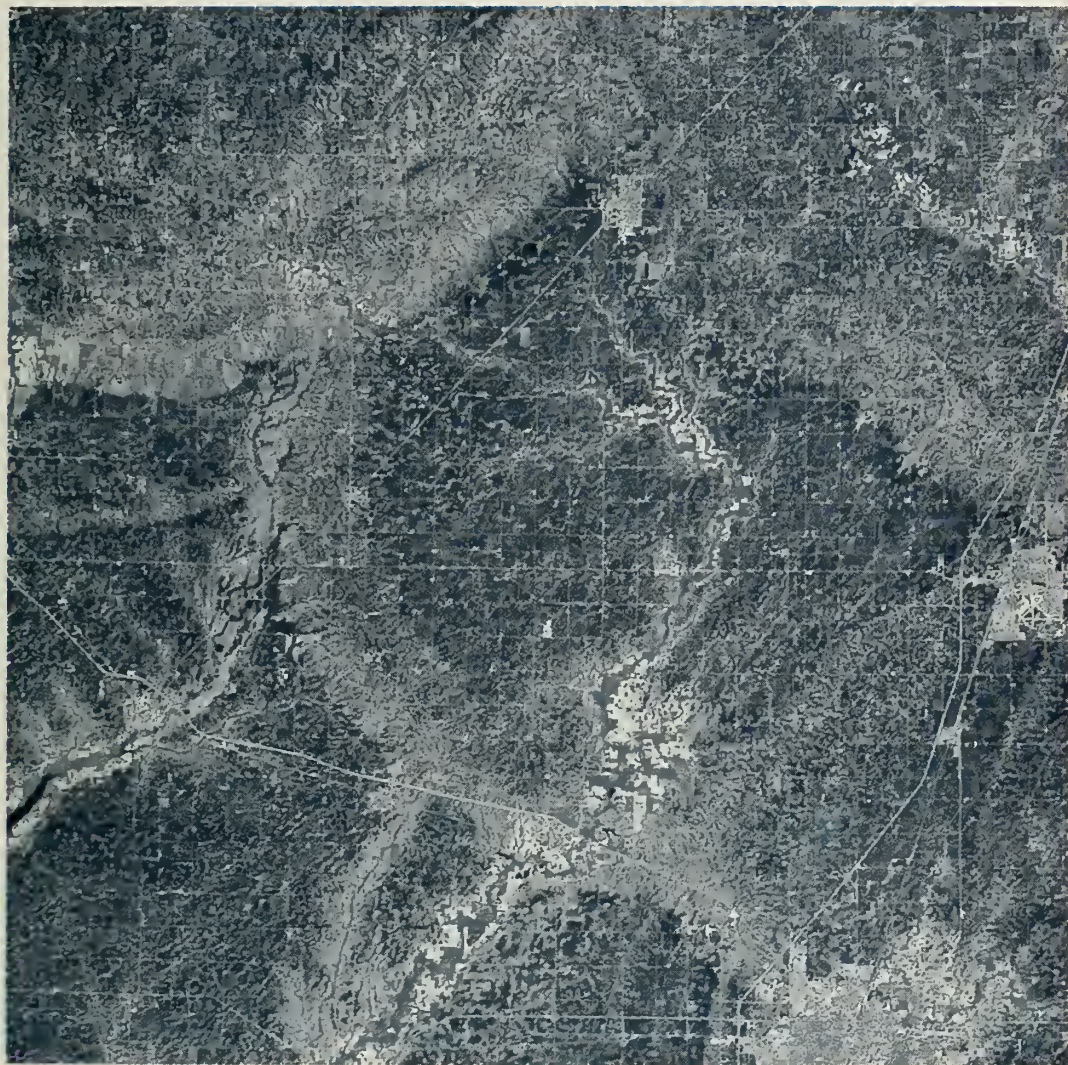


S  
14.GS:  
GES 14  
e.1

Geol Survey

# ILLINOIS' ICE AGE LEGACY

**Myrna M. Killey**



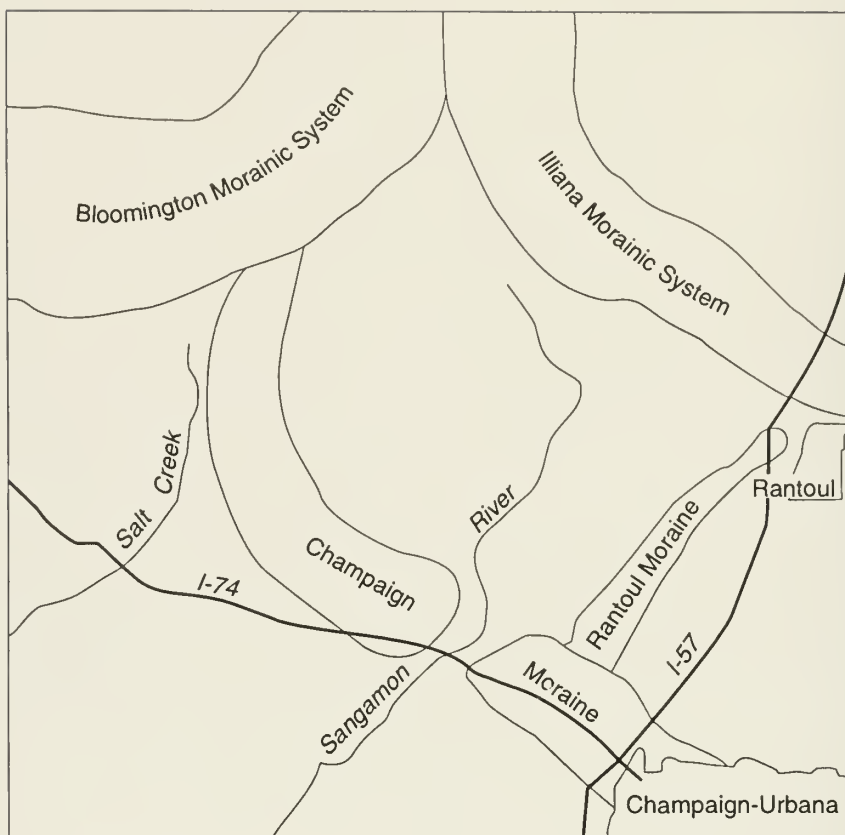
GeoScience Education Series 14 1998

ILLINOIS STATE GEOLOGICAL SURVEY  
Department of Natural Resources

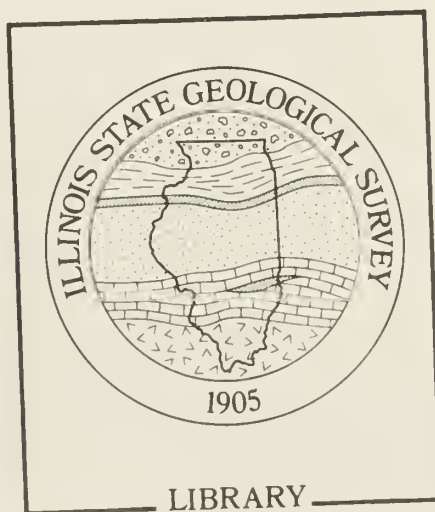
LIBRARY

APR 01 1999

IL GEO SURVEY



**Cover illustration** The long, curving ridges are moraines left by the last glaciation, 18,000 to 16,000 years ago, as viewed by *Landsat 1* from 440 miles above Illinois.



# ILLINOIS' ICE AGE LEGACY

---

**Myrna M. Killey**

GeoScience Education Series 14 1998

ILLINOIS STATE GEOLOGICAL SURVEY

William W. Shilts, Chief  
Natural Resources Building  
615 East Peabody Drive  
Champaign, IL 61820-6964  
(217) 333-4747

LIBRARY

APR 01 1999

IL GEO SURVEY

#### Editorial Board

---

Jonathan H. Goodwin, Chair	
Michael L. Barnhardt	Donald G. Mikulic
Heinz H. Damberger	William R. Roy
Anne L. Erdmann	C. Pius Weibel
David R. Larson	

---



Printed by Authority of the State of Illinois/1998/2,000

♻️ Printed with soybean ink on recycled paper



## FOREWORD

---

### *from the Chief*

Mention Illinois and most people think of flat rolling prairies that seem to go on forever. But a varied and fascinating geology is buried beneath the Illinois plains. A well driller boring down into Illinois passes through many different layers of soils, sand and gravel, pebbly clay, and silt before hitting bedrock. These varied deposits and the contours of the bedrock are due to the huge continental glaciers that repeatedly advanced and retreated across Illinois in the last 1½ million years.

A lot of what we take for granted in our daily lives—soil, water, and minerals, the resources that nurture all life and sustain our society—are the legacy of these glaciers.

Much of Illinois' economy and well-being depends on the riches we owe to the deposits, or drift, left by the glaciers.

- Illinois' rich agricultural lands developed in the windblown loess and till left by the melting glaciers.
- Much of our drinking water is pumped from aquifers that exist in glacial sands and gravels.
- The sand and gravel essential to every building and road project was left by runoff from the glaciers.

We also owe the diversity of our forests, prairies, and wildlife habitats to the different deposits and landscapes left by the retreating glaciers.

The importance of glacial drift was obvious to the writer Ignatius Donnelly back in 1883. He wrote of the drift covering much of North America:

It is our earth. It makes the basis of our soils; our railroads cut their way through it; our carriages drive over it; our cities are built upon it; our crops are derived from it; the water we drink percolates through it; on it we live, love, marry, raise children, think, dream, and die; and in the bosom of it we will be buried. (*Ragnarok: The Age of Fire and Gravel*)

But awareness of glacial deposits is important for another reason—preserving a safe and healthy natural environment for ourselves and our children. As citizens, we face many crucial health and environmental issues:

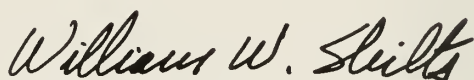
- keeping our drinking water, rivers, and streams free of contamination
- protecting against floods, earthquakes, and erosion of soil and beaches
- safe siting of land fills, agricultural facilities, and low-level radioactive waste disposal

- reclaiming land contaminated by previous generations
- maintaining natural areas and wetlands for hunting, fishing, boating, and recreation

All these issues involve landscapes composed of glacial deposits.

As citizens, your participation in finding local solutions to these problems will require a basic understanding of these glacial materials and how they were formed.

This book introduces you to the legacy of glaciers in Illinois: how geologists study and learn about them, the history of the many glaciations, and a description of the deposits they left in Illinois. I hope, when you next look out over Illinois' landscape, you'll see more than just flat prairies, and realize that much of what affects your daily life is a legacy of the massive glaciers that once covered Illinois.

A handwritten signature in black ink, reading "William W. Shilts". The script is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

William W. Shilts, Chief  
Illinois State Geological Survey

## CONTENTS

---

<b>INTRODUCTION: WHAT WAS THE GREAT ICE AGE?</b>	<b>1</b>
Why the Great Ice Age Is Important	2
Natural Resources	3
Soils, water, sand and gravel, natural gas, peat, fill material	
Geologic Hazards	4
Earthquakes, landslides, subsidence, swelling soils, floods and coastal hazards	
 <b>WHAT HAPPENED DURING THE GREAT ICE AGE?</b>	 <b>7</b>
Causes of the Great Ice Age	7
How Glaciers Formed	8
Evidence that an Ice Age Occurred	9
Earth and Rock Materials Left by the Ice	9
Till, outwash, loess, lake (lacustrine) deposits, erratics, scratches on bedrock	
Landforms Left by the Ice	14
End moraines, kames and kettles, eskers, glacial lake plains	
Other Evidence for the Ice Age in Illinois	17
Ice-wedge casts, patterned ground	
 <b>HOW DEPOSITS OF THE GREAT ICE AGE ARE STUDIED</b>	 <b>20</b>
What We Need to Know about the Great Ice Age, and Why	20
What Geologists Observe about Ice Age Deposits	20
Principles and Techniques Used to Decipher the Ice Age Story in Illinois	21
Age Dating	21
Relative age dating, radiometric age dating	
Drilling	22
Lithologic and mineralogical analysis, buried soils	
Putting It All Together	23
How Geologists Present the Current Understanding of Glacial Deposits	24
 <b>THE LANDSCAPE BEFORE THE GREAT ICE AGE</b>	 <b>29</b>
Investigating Bedrock in Illinois Today	29
Kinds of Bedrock Beneath the Glacial Drift	29
The Bedrock Landscape	31
Bedrock Uplands	31
Bedrock Valleys	31
The Driftless Area	33

<b>THE EARLIEST GLACIATIONS</b>	34
What We Know about the Earliest Glaciations	34
Source Areas of the Early Glaciers	36
Northwestern-Source Glaciers	36
Northeastern-Source Glaciers	38
Relationship between the Pre-Illinoian Deposits of Eastern and Western Illinois	38
Sediments Other than Till	38
Major River Systems after the Earliest Glaciations	39
The Yarmouth Soil: Distinguishing Pre-Illinoian Sediments from Younger Overlying Deposits	40
Finding Out More about these Earliest Glaciers	40
 <b>GLACIATIONS OF THE ILLINOIS AND THE WISCONSIN EPISODES</b>	 42
Illinois Episode Glaciation	42
Source Area of the Illinois Episode Glaciers	42
Extent of Illinoian Deposits	42
Number of Ice Advances during the Illinois Episode	43
Landscape of the Illinoian Glaciation	44
The "ridged drift"	
How Illinoian Glaciation Altered Major River Systems After the Illinoian Glaciation	45
Glaciation of the Wisconsin Episode	46
Source Area of the Wisconsin Episode Glaciers	46
Wisconsin Episode Deposits	46
Dating the Wisconsin Glaciation	48
What We Learn from Wisconsin Episode Sediments	48
How Wisconsin Episode Glaciers Altered Major River Systems	51
Distinguishing Wisconsin Episode Deposits from Older Illinois Episode Deposits	52
Landscapes of the Illinoian and Wisconsin Glaciations	52
Sediments Other than Till	54
After the Wisconsin Glaciation	54
Kankakee and Fox River Floods	54
Glacial Lake Sediments	55
Sand Dunes	55
 <b>EPILOGUE: ARE WE STILL IN THE GREAT ICE AGE?</b>	 57
 <b>FOR FURTHER READING</b>	 58
 <b>GLOSSARY</b>	 61
 <b>ACKNOWLEDGMENTS</b>	 66



# INTRODUCTION: WHAT WAS THE GREAT ICE AGE?

Although the earth is now calculated to be approximately 4.6 billion years old, the face of most of Illinois is quite young—mere thousands of years old. Due to various climate changes about 1.6 million years ago (some sources say about 2.5 to 3 million years ago, but still only yesterday in the scale of geologic time; see table 1), immense sheets of ice, called glaciers, flowed outward from centers of snow accumulation in Canada (fig. 1). Eventually, they crept far enough south to invade what is now Illinois. In time, the climate warmed again and the ice sheets melted away. Such episodes of ice advance and withdrawal occurred several times.

**Table 1** This geologic time scale shows how recent and short-lived the Great Ice Age was in comparison to the age of the earth. Periods and epochs for which no deposits are known in Illinois are shaded in blue at right. Rectangles along the right scale indicate the times of major ice ages in earth's history. (After Palmer 1983)

Eon	Era	Millions of years ago	Eon	Era	Period	Epoch	Millions of years ago	
Phanerozoic	Cenozoic	66	Phanerozoic	Cenozoic	Quaternary	Holocene	0.01	Great Ice Age
	Mesozoic	245				Pleistocene	1.6	
	Paleozoic	570			Tertiary	Pliocene	5.3	
		900				Miocene	23.7	
Precambrian	Proterozoic	1,600				Oligocene	36.6	
		2,500				Eocene	57.8	
		3,000				Paleocene	66.4	
		3,400						
	Archean	4,600		Mesozoic	Cretaceous		144	
					Jurassic		208	
					Triassic		245	
					Permian		286	
					Pennsylvanian		320	
					Mississippian		360	
	Paleozoic			Paleozoic	Devonian		408	
					Silurian		438	
					Ordovician		505	
					Cambrian		570	
					Precambrian			

Imbedded in each successive glacier were immense amounts of ground-up rock debris gouged out of the *bedrock* (words in italics are defined in the glossary) in Canada and the northern United States as the glacier slowly pushed southward. As the last glacier to reach Illinois melted and left behind the last load of rock debris, the land that emerged looked far different from the preglacial landscape. Hills and valleys on the old rock surface had been buried, new ones had been formed over them, and a thick mantle of ground-up rock debris—called *glacial drift*—lay over most of the land.

These continental glaciers affected Illinois in several unique ways. First, we have rock debris from glaciers that came from both the north-

western and the northeastern centers of ice accumulation in Canada (fig. 1). Second, drainageways for meltwater from the glaciers converged here from the northeast, north, and northwest (fig. 2). Third, the continental glaciers spread farther south in Illinois than anywhere else in the United States (37°30' N. latitude, in Johnson County; fig. 2).

Although the last glacier disappeared from Illinois between 14,000 and 13,000 years ago, to the geologist glaciers are very recent visitors to the state. Of the approximately 4.6 billion years of earth history (table 1), the Great Ice Age together with the following warm period that has lasted to the present make up only about the last 0.03% of that history! This period of time is called the Quaternary (pronounced Kwa-TURN-a-ree) Period (table 1). The time spanned by the Great Ice Age alone is called the Pleistocene (pronounced PLY-sto-seen) Epoch. The term Quaternary is probably more frequently used by geologists, because certain geologic processes affecting sediments deposited during the Great Ice Age are continuing on the landscape today. We use the term Qua-

ternary not only as the name of this most recent interval of geologic time, but also to refer to the earth materials that were deposited during this time.

### WHY THE GREAT ICE AGE IS IMPORTANT

In spite of their geologically short visit, the glaciers left a rich legacy of natural resources that first attracted native Americans and later Europeans to settle in what is now Illinois. Ice Age deposits also form the natural foundation for much of our construction—houses, cities, factories, highways, bridges, dams, and other structures. We must understand the characteristics of these materials and how natural processes affect them in order to identify and avoid potential hazards, such as landslides and unstable slopes, that may be associated with these materials. Finally,



**Figure 1** Glaciers spread southward into the Midwest from two centers of ice accumulation in western and eastern Canada.

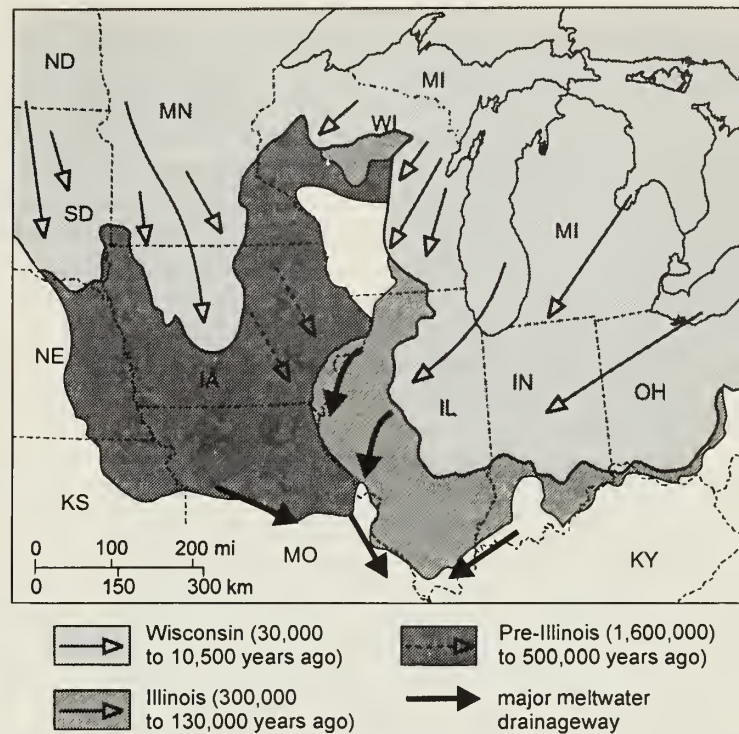
much of the waste produced by our society is buried in Ice Age deposits. Clearly, it behooves us to learn as much as we can about these interesting and useful materials.

## Natural Resources

**Soils** The rich soils of Illinois grow enough crops to feed much of the nation. These soils have developed in *loess*, a silt deposited by wind that blankets most of the state (see p. 11). Loess is one of the best possible parent materials for soil development: it is rich with a wide variety of minerals that crops need, it has a uniform and medium texture (neither as coarse grained and loose as sand and gravel nor as fine grained and sticky as clay), it contains no cobbles or boulders that can interfere with plowing, and it retains moisture well. Illinois' highly productive soils are one of the Ice Age's richest legacies to the state.

**Water** Water is our most essential resource. It originates as rain or snow and collects in lakes and streams or seeps into the ground to form groundwater. Groundwater supplies the water needs of approximately 50 percent of Illinois' population, and glacial deposits contain a large portion of our groundwater resources, although the amount varies from area to area. Where they are water-saturated, the numerous and widespread sand and gravel deposits throughout the glaciated area of Illinois serve as *aquifers* and provide amounts of water ranging from domestic supplies for individual households to large municipal supplies. Abundant supplies of groundwater help meet the heavy demand in large urban areas such as the greater Chicago region or the areas of southwestern Illinois that form part of the St. Louis metropolitan complex.

**Sand and gravel** In addition to being sources for groundwater, sand and gravel deposits provide excellent materials for numerous commercial and industrial uses, including concrete aggregate, construction fill material, road gravel, building sand, and molding sand. Sand and gravel deposits are evaluated by their thickness and extent, the thickness of any *overburden* (overlying deposits) that must be removed, the distribution of particle sizes, and the quality of the gravel for given uses. The most valuable gravel deposits contain at least 25 percent gravel and can produce large volumes of coarse and fine aggregate that have the right composition for use in concrete.



**Figure 2** The southern limits of major glacial advances into the Midwest. Major meltwater drainageways converged here from the northeast, north, and northwest. Open arrows indicate general direction of ice flow. (After Prior 1991)



**Natural gas (drift gas)** We generally think of natural gas occurring in association with petroleum. However, natural gas also forms in glacial deposits through the decay of organic matter in buried soils, peats, and organic-rich silts. The gas is confined to these layers or to porous layers of sand and gravel by thick, overlying deposits of mixed clay, silt, sand, pebbles, cobbles, and boulders called *till* (see discussion on p. 11). Several billion cubic feet of drift gas has been used to heat homes in Illinois over the years; it is a significant economic resource.

**Peat** Peat is partially decomposed and disintegrated plant matter formed by natural accumulation of plant materials in poorly drained areas such as bogs. Its occurrence in Illinois is spotty and localized, but peat is produced commercially in Lake and Whiteside Counties. It has horticultural uses as a soil conditioner to increase organic content, make clayey soils more friable (easily broken or pulverized), and increase moisture retention.

### IF WE STILL USE THE TERM “QUATERNARY,” WHAT HAPPENED TO PRIMARY, SECONDARY, AND TERTIARY?

The term Quaternary is a relic of the earliest attempts to subdivide the geologic record and establish a time classification scheme for the rocks and sediments observed at the earth's surface. Giovanni Arduino, an 18th-century Italian who studied the Alps and plains of Italy, based his classification scheme on the degree of metamorphism, structure, and hardening of the rocks he studied. He observed that the core of the Alps consists of crystalline rocks; because these were obviously the first formed, he called them **Primary**. The flanks of the mountains he studied are strongly deformed fossiliferous limestone and marble, and he named these strata **Secondary**. He classified the *unlithified* sediments of the plains **Tertiary**, and later he added alluvial (river) and lake deposits as **Quaternary**.

This scheme was useful for early geological studies and was applied elsewhere in Europe and America until the 1820s. As geologic understanding of other areas and mountain ranges grew, however, it became clear that all mountain ranges were not the same age and had not been formed in the same manner. The terms Primary and Secondary were therefore misleading and were eventually discarded. Attempts have been made to eliminate the terms Tertiary and Quaternary, but their use has persisted. The term Tertiary has come to refer to the often unlithified preglacial formations of the Cenozoic Era (see table 1), and Quaternary is used for the period from the beginning of the Ice Age to the present and for the sediments deposited during this time.

—Myrna M. Killey

**Fill material** Many construction projects require fill material to provide uniform foundation conditions for buildings. Most tills and clayey glacial deposits provide good fill material, although all such deposits require adequate engineering testing to determine their suitability for such use. Because they are widespread in Illinois, adequate quantities and quality of fill material are usually easily found.

### Geologic Hazards

Most of the damage from the geologic hazards we face in Illinois, from earthquakes and landslides to flooding and coastal erosion, occurs in glacial deposits. Planning to prevent or minimize damage depends on understanding the physical properties of the deposits.

An explanation about the nature of these deposits from an engineering point of view may be helpful. The tills deposited directly by the Ice Age glaciers are the thickest type of glacial sediment in Illinois, and they directly underlie the comparatively thin loess cover across vast areas of the state. Tills were deposited beneath the glacier and were overridden by glacial ice, in some areas by several successive ice sheets. The great weight of the ice consolidated the mass of individual grains of various sizes and com-

pacted them tightly together. For this reason, engineers consider tills to be *overconsolidated* because when subjected to certain standard types of engineering tests, they behave similarly to rock.

Many geologists, however, describe tills and other glacial deposits as “unconsolidated,” using the term in the sense of *unlithified*, because sufficient geologic time has not elapsed since their deposition for the processes of compaction and cementation to truly turn them into rock. In addition, even the most dense and massive “overconsolidated” tills, if they are moist enough, can generally be cut with a knife, pick, shovel, or other field implement, even though this can be done only with difficulty in some cases. Readers may encounter both “overconsolidated” and “unconsolidated” in reading about Ice Age deposits, and it is important to understand the different concepts each term is intended to convey according to its context.

**Earthquakes** Because the tills are overconsolidated in an engineering sense, they behave much like bedrock when they are subjected to seismic energy during an earthquake. However, loose, uncompacted, unconsolidated materials such as sand and gravel or lake silts may lose coherence when subjected to earthquake energy, especially when they are moist. When these sediments become saturated with water, the grains may lose contact with each other during the shaking of an earthquake. If this happens, they become “liquefied.” In this state, there is little grain-to-grain contact; instead, the grains float loosely in water. When liquefied, sands and gravels and lake silts may lose strength and no longer support buildings or other structures whose foundations were built in them. Thus, the geologic materials of an area, the degree to which they are saturated, how they behave when subjected to seismic energy, and their proximity to an earthquake epicenter (the point on the earth’s surface directly above the point of origin of an earthquake), must all be taken into account in determining how Ice Age materials may react in an earthquake. Another factor to be kept in mind is that earthquake tremors can loosen earth materials that occur on otherwise stable slopes and can directly trigger landslides.

**Landslides** If glacial deposits occur along steep stream banks or roadcuts, slumping and landsliding may result, especially after heavy or prolonged rains. The causes of landsliding in Illinois are numerous, and landslides may involve bedrock, Ice Age deposits, or both. Again, saturated sediments tend to lose coherence and cause slope failure, so understanding the geologic setting is crucial to determining the susceptibility of an area to landsliding.

**Subsidence** Most subsidence in Illinois takes place over underground coal mines and involves Ice Age materials only to the extent that collapse of a mine roof causes the overlying earth materials, including glacial deposits, to subside, or sink. However, some Ice Age deposits can cause damage to building foundations, as discussed below, in ways that may mimic the effects of mine subsidence.

**Swelling soils** Some glacial deposits with large amounts of certain types of clay minerals expand when wet and shrink when dry. After decades of cycles of shrinking and swelling, small cracks open and fill with earth, leaves, twigs, and other debris; during swelling cycles, pressure can build up against foundation walls of houses and other buildings and cause cracking and tilting of walls and floors. Similar behavior can result from



cycles of freezing (expansion) and thawing (contraction) of water in the pores of soils.

**Floods and coastal hazards** Because Ice Age sands and gravels and more recent floodplain deposits exist in our major river valleys, and because the Lake Michigan coastline also consists of glacial deposits, studying the properties of these sediments helps us understand their susceptibility to erosional and depositional processes of river floods and coastal waves. During the Great Flood of 1993, for example, floodwater inundated towns and large areas of farmland in the river floodplains. In some places, the water deposited great volumes of sediment, and in others, eroded support from around bridge abutments and building foundations. Over many years, erosion of beaches and shorelines and undercutting of lake bluffs by wave action has caused considerable damage to land and structures along Illinois' Lake Michigan coastline.

Many of us live, work, and play on Ice Age deposits every day but rarely think about their contributions to our daily lives. This booklet introduces the reader to the fascinating legacy left to Illinois by those massive ice sheets that covered the state so many thousands of years ago.

A comprehensive, well-illustrated, and easily understood discussion of geologic hazards is found in Edward B. Nuhfer and others, *Citizens' Guide to Geologic Hazards* (1993), published by the American Institute of Professional Geologists, 7828 Vance Drive, Suite 103, Arvada, CO 80003; telephone (303) 431-0831.

More information on landslides in Illinois and the Ice Age materials involved in certain types of landslides can be found in Myrna M. Killey, Jennifer K. Hines, and Paul B. DuMontelle, *Landslide Inventory of Illinois* (1985).

More information on how swelling soils can damage homes and buildings is available in Robert A. Bauer, Billy A. Trent, and Paul B. DuMontelle, *Mine Subsidence in Illinois—Facts for Homeowners* (1993).

More information on flooding and coastal hazards can be found in Michael J. Chrzastowski and others, *The Great Flood of 1993—Geologic Perspectives on the Flooding along the Mississippi River and Its Tributaries in Illinois* (1994), and S. Jeffress Williams, Kurt Dodd, and Kathleen K. Gohn, *Coasts in Crisis* (1990).

## WHAT HAPPENED DURING THE GREAT ICE AGE?

*If you had been able to view the North American continent from space during the Ice Age and to drastically speed up time, you would have seen an awesome sight. Two centers of ice accumulation would suddenly have appeared in Canada, and ice sheets would have spread rapidly outward from these centers until they covered much of the northern half of the continent (fig. 1). You would then have seen the ice fronts pulse back and forth across Canada and the Midwestern states many times before finally receding to their present location. If you had zoomed in closer as the ice melted, you would have seen huge streams of water flowing away from the front of the ice and down the major river valleys we know today. Today's geologists would give a lot to be able to see what you would have seen.*

### CAUSES OF THE GREAT ICE AGE

Although the reasons why the climate changed to conditions permitting the growth of continental glaciers are not fully understood even today, scientists think that the following factors played key roles.

Segments of the earth's outermost rigid, rocky shell (called "plates") slowly but continuously shift their positions in relation to each other. These large-scale movements and resulting deformations of the earth's crust are part of the concept of "plate tectonics." (Interested readers can look for discussions of plate tectonics in any recent general geology textbook.) As the crustal plates eventually reach configurations in which a substantial portion of the earth's land area is located near the poles, they form barriers to the flow of warm winds and ocean currents from the tropics to the polar regions. Such an arrangement of continents cools the high latitudes and allows the buildup of snow, which eventually forms glacial ice. These movements of the earth's plates could account for the three major glacial ages throughout earth's history: the first one, about 700 million years ago (during late Precambrian time), the second one, about 300 million years ago (during the Pennsylvanian Period), and the third one, the Great Ice Age, about 1.6 million years ago (the Pleistocene Epoch of the Quaternary Period; see table 1).

Within a single glacial age, there are numerous fluctuations of climate, which could account for the waxing and waning (expanding and contracting) of major continental glaciers. A great deal of evidence suggests that these climate cycles are due to cyclic variations in the shape of the earth's orbit around the sun, the tilt of the earth's axis relative to the plane of the earth's orbit around the sun, and the times of the year when the earth is closest to the sun as it moves through its elliptical orbit. Periodically, these

Ideas about possible factors affecting global climate that would result in an ice age are discussed in more detail in E.C. Pielou, *After the Ice Age* (1991), and John Imbrie and Katherine P. Imbrie, *Ice Ages—Solving the Mystery* (1979).

orbital variations reduce the contrast in temperature between summer and winter and produce extended periods with cool summers. In these periods, the previous winter's snow does not melt completely, and ice and snow gradually accumulate. The increased area blanketed by light-reflecting ice helps to further cool the climate by reflecting more of the sun's energy back into space; the growth of a continental ice sheet reinforces the climatic effects that make it grow.

These cycles of climate variations occurred many times throughout the Pleistocene Epoch. Studies conducted over the last two decades indicate that during the Great Ice Age, glaciers spread out and then receded on the North American continent perhaps as many as a dozen times, with many more minor pulses. Some scientists believe that we are presently in the midst of another interglacial age and that within the next few thousand years, glaciers may yet again advance into the interior of the North American continent. One factor complicating this proposed scenario is the warming of the climate that may result from the addition into the atmosphere of manmade pollutants.

## **HOW GLACIERS FORMED**

As the climate became cooler, snow that fell in northern regions during the winter did not completely melt during the summer. It did, however, recrystallize into granular ice. Over many hundreds of years, the snow and granular ice accumulated to such a thickness that the lower layers, weighed down by the thick overlying snow and ice, recrystallized into solid ice. Eventually the ice became so thick (at its maximum, perhaps 8,000 to 10,000 feet thick in central Canada) that it began to flow outward under its own weight. It is this flow that distinguishes glaciers from all other forms of ice accumulation. The building-up

## **THE ROLE OF MODERN GLACIER STUDIES IN INTERPRETING DEPOSITS OF ICE AGE GLACIERS**

Even though we can find abundant evidence in the landforms and deposits of Illinois that continental glaciers invaded the state many times during the Great Ice Age, glaciers remain a very exotic concept for most people living in Illinois. The nearest glaciers are thousands of miles away, mostly in fairly remote areas far from population centers. Thus it is hard for most of us to imagine what it must have been like in Illinois 20,000 years ago when a vast lobe of ice extended across the northeastern quarter of the state.

The concept of a Great Ice Age, a time when glaciers were once much more extensive than they are today, was first proposed by scientists, like Louis Agassiz from Switzerland, who grew up in countries where glaciers could be readily observed. One of the best ways to understand the glacial landscape and deposits of the Ice Age is to study existing glaciers that might serve as models of the Ice Age glaciers; doing so uses the fundamental principle in geologic studies that "The present is the key to the past."

Modern glaciers lure scientists to Iceland, Greenland, Antarctica, Patagonia, the Alps, eastern Canada, and Alaska. Although no present-day glaciers in these high-latitude and/or high-altitude areas are perfect models of the Ice Age glaciers that reached the mid-latitude area of Illinois, study of these glaciers has increased our understanding of the dynamics and complexity of glacial environments.

Geologists have been able to observe first-hand many of the processes occurring in modern glacial and *proglacial* environments and see the resulting landforms and deposits. Some of these processes take place very rapidly. Where one day there is a large lake dammed by ice or sediment, the next day there is only a barren lake bed with a channel cut through the former dam. Likewise, on a sunny summer's day when melting is at its greatest, small glacial streams in the morning can become raging torrents rumbling with



and flowing-outward continued for such a long time that the resulting glacier eventually flowed southward into Illinois. When the climate warmed enough so that the rate of melting in the summer exceeded the rate of spreading outward, the ice front ceased expanding and began to recede as the mass of ice itself gradually melted, a process known as *ablation*.

## EVIDENCE THAT AN ICE AGE OCCURRED

Illinois' present landscape bears witness to the presence of the massive continental ice sheets that visited the area many times over the past one to two million years, and to the dynamic interplay of depositional and erosional processes associated with the ice. The evidence consists of the earth

and rock materials blanketing Illinois' bedrock surface, and the landforms left behind on today's landscape.

### Earth and Rock Materials Left by the Ice

Approximately 90 percent of Illinois is blanketed by layers of unlithified sediment. In places this sediment, commonly called glacial drift, is more than 400 feet thick, and it probably averages about 100 feet thick. We know this sediment was deposited by processes related to glacial ice because we see some of the same types of sediments deposited by today's glaciers in Alaska, Greenland, Switzerland, South America, Antarctica, and elsewhere. There we can study the processes responsible for depositing glacial drift.

Although a mental picture of a mass of pure, pristine blue-white ice covering our part of the continent is attractive, a look at glacial ice today (fig. 3) shows that, in fact, it contains rock debris that was plucked from underlying bedrock, ground up, and embedded in the lower part of the ice as it moved forward. The continental glaciers, massive as they were, must have been very dirty indeed to

boulders by afternoon. As meltwater is added to debris that has melted out on the glacier surface, the mixture can become a muddy slurry that cascades off the ice front. On windy days, the sky may be filled with clouds of dust lifted from dry meltwater channels, eventually to be carried far from the glacier.

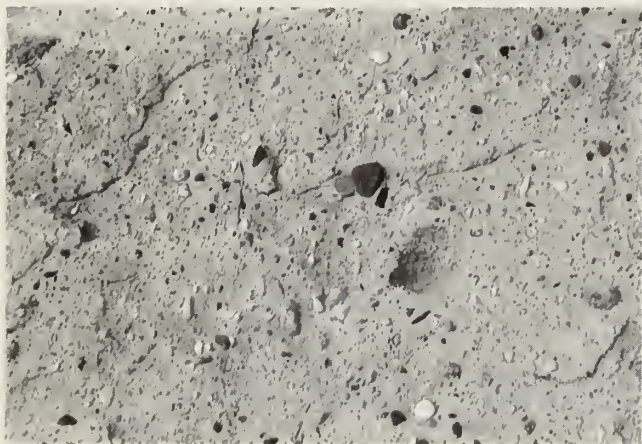
Because we cannot see directly beneath a glacier, what happens there remains something of a mystery to scientists. Only at the very margin of the glacier can we crawl into tunnels to observe what goes on under the ice. To infer what processes operate at the base of the glacier, geologists must rely on indirect observations from ice cores and seismic records. Long-term historical studies also have allowed scientists to infer what happens as glaciers expand, remain stable, or shrink through time. For example, over the last 45 years, geologists have been able to observe the landforms and deposits emerging from beneath the shrinking Burroughs Glacier in Alaska. These observations suggest models that might explain some of the landforms and deposits we see in Illinois. These models then must be tested against observable evidence in the landforms and deposits. Such studies often suggest ways the models need to be modified. By such cross-checking between concepts and observations, geologists can improve both their models of how glaciers work and their understanding of the glacial landscape and deposits.

For example, from modern glacier studies in Iceland and Antarctica has come the idea that when glaciers move over soft sediment rather than bedrock, the soft sediment may deform as water is added to it. The result is a glacier moving over a bed of deforming sediment. Some geologists have suggested that the Ice Age glaciers in Illinois moved by such a process. The homogeneous tills we find in Illinois might be a result of sediment mixing in a deforming bed beneath the glacier, rather than the result of simple melting at the base of the glacier. Geologists are now studying the tills in Illinois to see if the deforming bed hypothesis could account for our homogeneous till beds.

—Ardith K. Hansel



**Figure 3** Bands of sediment sheared into the ice can be seen on the face of this tidewater glacier in Glacier Bay, Alaska. (Photo by Myrna M. Killey)



**Figure 4** Till exhibits a variety of grain sizes packed tightly together. This picture shows an area approximately 2 feet by 3 feet of an outcrop of till. (Photo by Richard C. Anderson)



**Figure 5** This sand-and-gravel quarrying operation near Fox Lake, Illinois, shows outwash sand. The layers, or beds, of sand dip to the left, indicating that the meltwater flowed in that direction. (Photo by Richard C. Anderson)



**Figure 6** Loess has uniform grain size and tends to stand in vertical slopes, as shown in this roadcut along the east bluffs of the Missouri River valley. (Photo by Richard C. Anderson)



have left behind the immense amounts of sediment now overlying our bedrock.

**Till** Moving glacial ice gouges out or otherwise incorporates, grinds up, and carries along rock particles in a jumbled mass. This debris ranges from tiny clay particles smaller than the eye can distinguish, through silt (about the size of grains of flour) and sand-sized particles, to pebbles, cobbles, and boulders. Over broad expanses of Illinois, these rock grains of all sizes are jumbled and packed tightly together in a deposit called *till* (fig. 4). Till was plastered onto the pre-existing landscape at the base of the ice sheet as it slowly moved forward, or was left behind as irregular layers when the glacier melted.

**Outwash** In contrast to till, other glacially deposited materials have been sorted by size, indicating that some type of sorting agent—usually water or wind—has been at work on the sediments. It is easy to imagine streams of water pouring forth from the edge of the melting ice, first dropping (“washing out”) their load of coarser, heavier materials such as gravel and sand (called *outwash*; fig. 5) near the ice margin but carrying the finer material such as silt and clay farther downstream. Many sand and gravel operations in Illinois today expose these outwash sediments for us to see. Where we find a broad area of coarser (larger) grains such as gravel, we can be reasonably sure that the front of the ice once stood close by. In addition, we know from drilling that layers of outwash commonly are buried beneath and often alternate with layers of till. Such sequences of layers of till and outwash tell us that glaciers came and went across the area several times.

**Loess** The sediment-choked beds of meltwater streams would often dry out enough, especially during winter when glacial melting was greatly reduced, that winds could pick up the finer particles of silt, clay, and fine sand and deposit them over the landscape. This wind-deposited material is called loess (rhymes with “bus”; fig. 6). We occasionally see the same process today when strong winds pick up loose soil from dry, freshly

## WHAT ON EARTH IS “DIAMICTON” ?

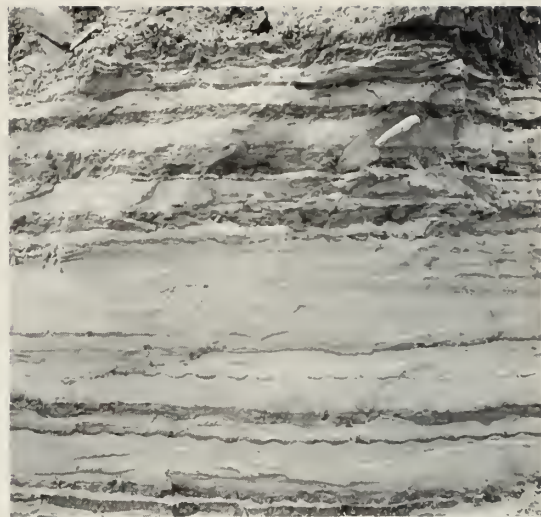
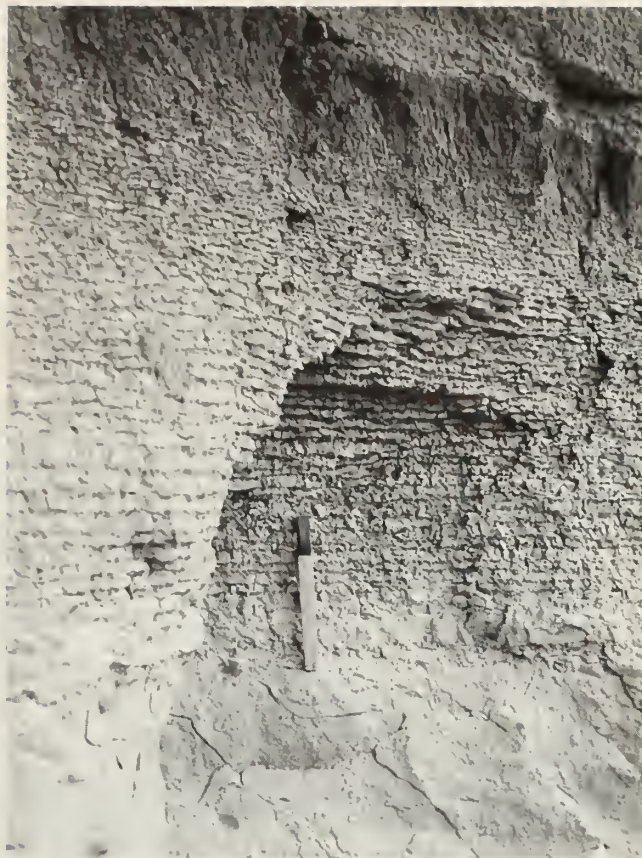
The word *till* has been used for many years to describe any sediment displaying a range of grain sizes, from clay to boulders, that was deposited by glacial ice. More sophisticated terminology has developed as our understanding of how various materials were deposited has increased.

Many geologists now restrict the term *till* to mean only the sediments consisting of a mixture of grain sizes deposited directly onto the landscape beneath the ice when the sheer weight of the overlying ice causes the base of the glacier to melt. This use of the term *till*, therefore, implies a particular way that the sediment is deposited.

However, mixtures of water-saturated, till-like sediment can also be deposited in other ways. For example, deposits with a wide range of grain sizes can occur when saturated sediment gradually creeps down a slope and settles at its bottom; no glacial ice is involved. Even in a glacial environment, debris-laden ice at or near the glacier’s margin can melt and flow away from the ice as a slurry of sediment and water, rather than be deposited beneath the ice. Thus, it is not always possible to determine exactly how the jumbled mix of grain sizes (till-like material) we see today was deposited.

To describe a till-like mixture of grain sizes without implying anything about its origin, not even whether it was deposited by glacial ice, many geologists now use the term *diamicton* (pronounced dye-a-MIK-tahn). However, because the term *till* is still commonly used and is simpler to remember, we use it in this booklet for all jumbled mixtures of grain sizes thought to be deposited by glaciers. Nevertheless, if you should hear someone use the term *diamicton*, you will know what on earth the term refers to.

—Myrna M. Killey



**Figure 7** (left) Rhythmites in lake sediments overlying a debris flow in a glacial lake in Minnesota. Similar deposits are present locally in Illinois. (Photo by Richard C. Anderson) (above) These layers of interbedded clays (dark layers) and sands (light layers) were deposited in a spit by longshore currents in ancestral Lake Michigan. (Photo by Ardith K. Hansel)

plowed, unplanted fields, blow it across the landscape, and create dust storms that can reduce visibility nearly to zero. Eventually the dust may be deposited as low ridges across fields and highways.

**Lake (lacustrine) deposits** In some places, glacial meltwater was temporarily dammed between the ice front and morainic ridges (see p. 14) and formed quiet-water lakes and ponds in which fine silt and clay (mud) settled out—just as occurs in many lake bottoms today. Eventually these lakes disappeared as the volume of meltwater lessened and stream erosion lowered the level of the lake outlets. Many former lakes and ponds have been identified on today's land surface by their uniformly fine grained deposits left in a very flat plain; these lake-deposited silts and clays are called *lacustrine* deposits by geologists ("lac" is French for "lake"). Sometimes these sediments show thin alternating layers (called *rhythmites*) that represent cyclical fluctuations in sediment deposition (fig. 7).



**Figure 8** This large igneous boulder is called an erratic because it is unlike the bedrock of Illinois. It, and many others like it, were carried by glaciers southward from Canada into the Midwest. (Photo by David L. Reinertsen)

erision lowered the level of the lake outlets. Many former lakes and ponds have been identified on today's land surface by their uniformly fine grained deposits left in a very flat plain; these lake-deposited silts and clays are called *lacustrine* deposits by geologists ("lac" is French for "lake"). Sometimes these sediments show thin alternating layers (called *rhythmites*) that represent cyclical fluctuations in sediment deposition (fig. 7).

**Erratics** One occasionally sees boulders lying on the landscape of Illinois (fig. 8);



they may be piled up in the corners of farm fields or used for landscape decoration. When we examine the boulders closely, we discover that many of them are *igneous* and *metamorphic* rocks quite unlike the *sedimentary* rocks that make up the bedrock of Illinois. These boulders are called *erratics* because of their erratic occurrence far from areas where igneous and metamorphic bedrock is exposed at the surface. But if they are unlike the sedimentary rocks found in Illinois' bedrock, where

did they come from and how did they get here? It turns out that similar igneous and metamorphic rocks occur at the bedrock surface in much of Canada, Minnesota, northern Wisconsin, and Upper Michigan. The only way such large boulders could have been transported to Illinois naturally was by the continental glaciers of the Ice Age, because no rivers existed that could roll such large boulders across such distances. Erratics may be somewhat rounded by being abraded during transport by the glacier.

**Scratches on bedrock** Although scratches on bedrock (called *glacial striations*) do not actually consist of earth or rock material left behind by the ice, such scratches (fig. 9) are additional convincing evidence that



**Figure 9** This polished bedrock surface shows striations (scratches) caused by rocks frozen into the base of a glacier that pushed relentlessly across the land surface. (Photo by W. Hilton Johnson)

## HOW ICE AGE DEPOSITS WERE ORIGINALLY INTERPRETED AND WHAT OBSERVATIONS LED TO THEIR CURRENT INTERPRETATION

Arduino's time classification, in which he placed alluvial (river) and lake deposits in the Quaternary time period, provided the impetus for the initial classification of geologic features observed in the Alpine region of Europe. Large boulders (erratics) unlike the local bedrock were seen that rested nearly 60 miles from their likely source in the Alps. Whalers had noticed rocks and boulders in icebergs breaking off the glaciers that covered much of Greenland.

These observations were used as evidence that the erratics resulted from drifting icebergs during a great flood (interpreted by some to be the Biblical flood). Thus the boulders and sediments resulting from these supposed drifting icebergs were called *drift* and were thought to be deposited by water; hence, they were classified as belonging to the Quaternary Period. The present use of the term *drift* for deposits of

Quaternary time is a holdover from the earliest interpretations of the origin of these materials.

Natural scientists in the late 1700s and early 1800s, however, observed that erratics, scratched and polished bedrock, and ridgelike end moraines on valley floors could also be plainly seen in the vicinity of existing Alpine glaciers. From these observations and associations, the idea that glaciers once existed over a much broader area began to evolve. In 1837 Louis Agassiz first presented before the Swiss Society of Natural History the idea that glaciers once covered a much greater extent of the landscape than they do today. He and others noted deposits on the lowlands of western Europe that were similar to those adjacent to glaciers in the Alps. These observations convinced Agassiz and others that deposits on lowlands in front of the Alps were formed by earlier, more widespread glaciers.

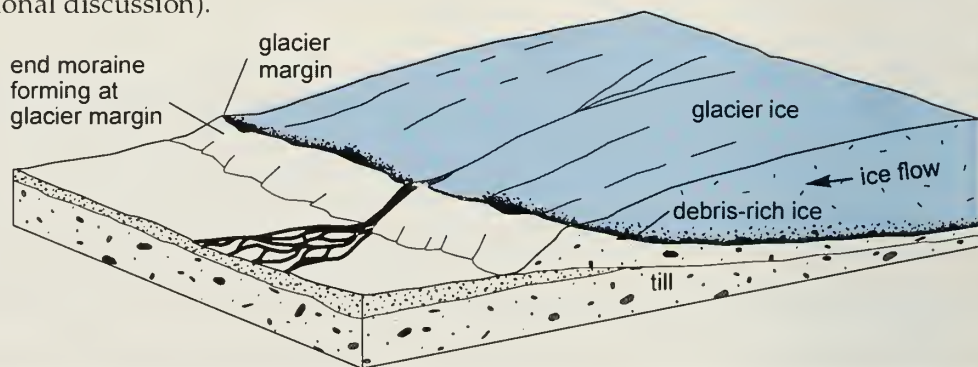
—John P. Kempton

continental glaciers advanced into Illinois. In several places where bedrock is exposed at the ground surface, especially in limestone and dolomite quarries in northeastern Illinois, the bedrock displays a smooth, almost polished surface that bears numerous scratches, most of them trending in a northeast–southwest direction. The most convincing explanation for this scratched and polished bedrock surface is that rocks frozen into the base of the glacier, especially granite and other igneous and metamorphic rocks harder than the local bedrock, abraded the underlying bedrock as the ice dragged them along. The orientation of the striations tells us the ice generally moved southwestward across Illinois (see fig. 2).

### Landforms Left by the Ice

Glaciers of the Ice Age left distinctive landforms typical of continental glaciation as part of the modern landscape. Although these landforms are discussed further in the chapter “Glaciations of the Illinois and Wisconsin Episodes,” they are briefly introduced here because they are important evidence that continental glaciation took place in Illinois.

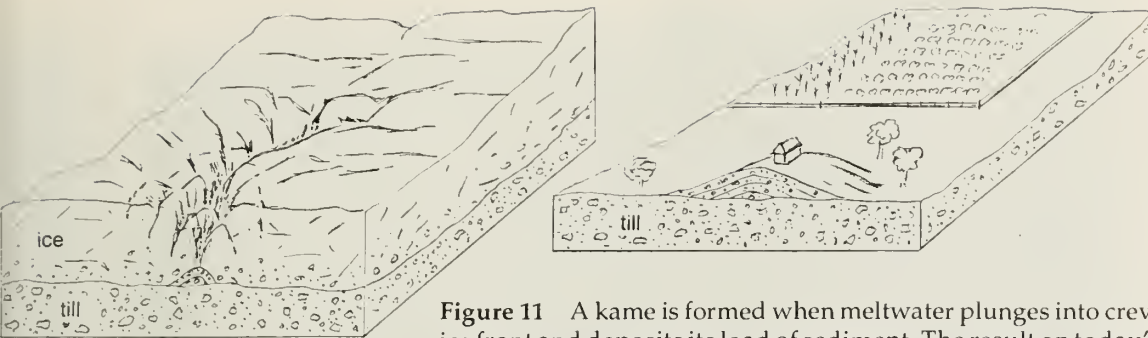
**End moraines** Huge, curved ridges of till outline where the outer margin, or end, of the lobe-shaped glacier once stood. These *end moraines* (fig. 10) were formed along the edge of the ice when the rate of ice advance approximately equaled the rate of melting, causing the ice margin to remain stationary. The ice within the lobe kept moving forward, however, delivering more rock debris to the ice front, where it piled up. These end moraines (more commonly just called “moraines”) sometimes exhibit a hummocky land surface characterized by rounded knolls and depressions, called knob-and-kettle *topography*. Examples of moraines that exhibit this kind of surface are the Marseilles, Bloomington, and Shelbyville Morainic Systems (see fig. 24 for a map of moraines in Illinois and p. 54 for additional discussion).



**Figure 10** From the crest of the Bloomington Morainic System in northern De Kalb County, Illinois, one can look west across an older landscape. (Photo by Richard C. Anderson)



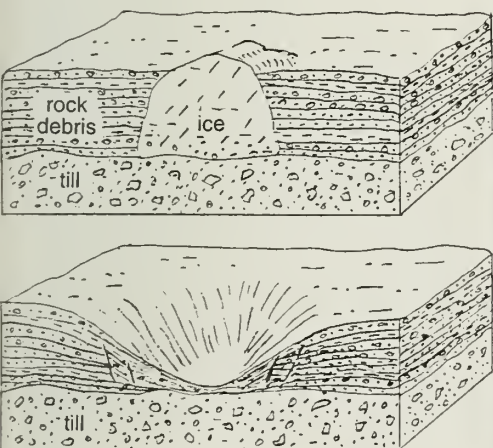




**Figure 11** A kame is formed when meltwater plunges into crevasses near the ice front and deposits its load of sediment. The result on today's landscape is a low mound composed of sand and gravel, such as this one in southern Champaign County. (Photo by David L. Reinertsen)



**Kames and kettles** Mounds of sand and gravel, called *kames*, formed when meltwater plunged into *crevasses* near the ice front and deposited its load of sediment (fig. 11). As the glacier melted away, the sand and gravel gradually collapsed into a gentle mound on the landscape. Numerous examples exist in Illinois, among which are several in the "ridged drift" complex (described on p. 44–45) and Blue Mound and Long Mound on the Macon-Christian County border. Depressions on the landscape, called *kettles*, formed where blocks of ice, detached from the main ice sheet and surrounded by rock debris from the melting glacier, themselves finally melted (fig. 12). The depressions left on the landscape today may be



**Figure 12** A kettle is formed when blocks of ice become detached from the main glacier and are surrounded by rock debris from the melting glacier. When the ice blocks

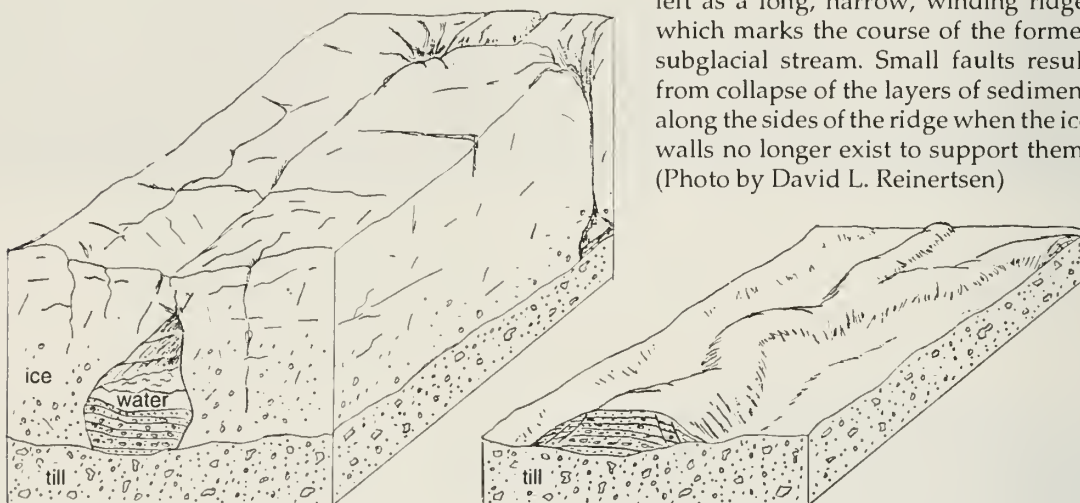
melt, they leave depressions on the landscape. Small faults result from collapse of the layers of rock debris into the depression. (Photo by David L. Reinertsen)





**Figure 13** An esker is formed when a stream of meltwater carrying sediment and rock debris develops beneath a glacier. Such a stream may meander a little as it winds its way underneath the glacier toward the front of the ice. The sand and gravel is deposited when the meltwater gradually slows and drops its load of rock debris. When the ice melts away, the sediment and rock debris are

left as a long, narrow, winding ridge, which marks the course of the former subglacial stream. Small faults result from collapse of the layers of sediment along the sides of the ridge when the ice walls no longer exist to support them. (Photo by David L. Reinertsen)



swampy or dry. Dry depressions may hold water for a while after prolonged and heavy rains, and deep kettles may actually contain lakes. Examples of kettles can be seen in the knob-and-kettle topography of some end moraines.

**Eskers** A type of glacial landform less commonly found in Illinois is an *esker*, a long, narrow, winding ridge of sand and gravel deposited by a stream of meltwater flowing at the base of a glacier (fig. 13). These streams carried rock debris such as sand and gravel, just as streams do today, and also meandered a little, as some streams do today, as they wound their way at the base of the ice toward the ice front. The sand and gravel was deposited as the meltwater stream gradually slowed and could no longer carry its load of debris. The ice then melted away, leaving this sediment in place to mark the course of the former subglacial stream. Eskers are not common in Illinois, but a group of small eskers exists on the backslope of the Bloomington Morainic System in Bureau County. Because kames and eskers are easily accessible sources of sand and gravel, many, such as the Kaneville esker in Kane County (one of our better-known eskers), have been mined and no longer exist.

**Glacial lake plains** Exceptionally flat areas, called *glacial lake plains*, may occur between end moraines. These plains are underlain by lacustrine silts and clays deposited in the quiet waters of temporary meltwater lakes that were dammed between an end moraine and the edge of the retreating ice front. Examples include a large area in Grundy and southern Kendall Counties between the Marseilles Morainic System to the west and the Minooka Moraine to the east, and in central Douglas County between the Arcola Moraine to the south and the Pesotum and West Ridge Moraines to the north (see fig. 24 for a map of moraines).

## OTHER EVIDENCE FOR THE ICE AGE IN ILLINOIS

Additional evidence that much colder temperatures were once widespread across Illinois and the Midwest takes several forms, including fossils, pollen, ice-wedge casts, and patterned ground.

Every now and then, newspapers will carry a story describing a new find of partial skeletons of mastodons or mammoths, usually in northeastern Illinois. These animals, close relatives of modern elephants, roamed the open meadows, forests, and *tundra*-like Illinois landscape within a few miles of the glacier. Mammoths grazed on the grass and vegetation that existed on the tundra, and mastodons browsed on saplings in the partly forested landscape (fig. 14). As the climate became warmer and their environment changed, the mastodons and mammoths disappeared, becoming extinct about 7,500 years ago.

The existence of an Ice Age environment can also be demonstrated by examining fossil pollen, which is often found in the fine grained sediments and peat deposited in glacial lakes. The fossil pollen indicates that, at the end of the last glaciation, much of northern and central Illinois resembled the forest and tundra landscape that exists today in northern Canada. Forested areas were dominated by spruce, pine, and sedge. The more open



**Figure 14** This scene might have occurred near the margin of the Wisconsin Episode ice sheet about 14,000 years ago. Mastodons browsed on spruce, pine, and other

plants that thrived in a cold climate. Reconstruction painting by R. G. Larson, used with permission of the Illinois State Museum, Springfield, Illinois.





**Figure 15** The size of this sediment-filled ice-wedge cast in Vermilion County, Illinois, can be estimated by the shovel below the exposure. (Photo by W. Hilton Johnson)

tundra-like areas were dominated by arctic, aquatic, and wetland plants. The fossil pollen in younger sediments shows that there were widespread changes from species that thrive in colder environments to those that grow in warmer, drier conditions; these changes signal that the climate was becoming more like today's.

Finally, special features called *ice-wedge casts* and *patterned ground* have been found on the Illinois landscape. Similar features are found in areas where *permafrost* exists today. Therefore, we can conclude that the Illinois landscape once had conditions similar to those where permafrost exists today.

**Ice-wedge casts** are sediment-filled fissures (fig. 15) that formed when ice or hoarfrost (tiny ice crystals) filled narrow cracks in sediment that resulted from thermal contraction at the ground surface. They are most commonly found in the central and northern half of Illinois.

**Patterned ground** refers to polygonal patterns that develop on the ground surface in poorly drained areas where intensive frost action takes

place. The polygons, best seen in aerial photographs (fig. 16), are outlined by slightly darker soils that accumulated in the swales (sunken areas) surrounding the polygons. Patterned ground is found in areas that had tundra-like conditions during the last major glaciation.

**Figure 16** This aerial photo taken near Clinton, Illinois, shows typical patterned ground that develops on the ground surface in poorly drained areas where intensive frost action has taken place. The patterned ground can be seen here as a mottled appearance over the entire photograph; the light and dark rectangles and strips are farm fields. (Photo by W. Hilton Johnson)



This chapter has presented much of the evidence that demonstrates that Illinois was covered by continental glaciers, and most of this evidence can be seen on or close to the land surface. But in order to understand more about the character of the glacial drift, how it occurs, and how we can best use it in environmentally acceptable ways, we need to examine this evidence in the third dimension, that is, from the bedrock surface on which it lies up to the ground surface. Also, to better understand the sediments themselves, we need to know something about the methods scientists use to investigate Ice Age deposits in Illinois. First, in the next chapter, we will see how geologists study Ice Age sediments; then in the following chapter, we will examine what we know about the bedrock surface largely buried by these sediments.

## HOW DEPOSITS OF THE GREAT ICE AGE ARE STUDIED

*The prehistoric hunters who lived near the Ice Age glaciers left no records of what they saw, so scientists must do the next best thing—study as much evidence as they can find about this fascinating chapter in earth’s history. Advances in understanding the world around us must come through rigorous application of the scientific method—making observations, devising hypotheses to explain the observations, then testing the hypotheses. Yet, in attempting to find out what happened during the Ice Age, creativity and imagination are also vital. A geologist with creativity and imagination can envision how things might once have been.*

### **WHAT WE NEED TO KNOW ABOUT THE GREAT ICE AGE, AND WHY**

Advances in science are often driven by the need to know something, but just as often they are driven by simple curiosity. Both curiosity and the need to know have been forces behind the desire to understand as much as possible about the Ice Age.

The need to know comes from society’s demand for water, sand and gravel, and other mineral resources, our need to dispose of waste in the safest possible environment, and the need to understand as much as possible about geologic hazards in order to lessen their effects. In the Midwest, drilling into the earth usually encounters glacial deposits before reaching bedrock. Deposits of sand and gravel can yield water and are used in concrete for roads and buildings. Tills, on the other hand, can be excellent natural repositories for holding waste. When it was recognized that glacial deposits could satisfy many of society’s economic needs, it became necessary to understand and map the character, distribution, and extent of all kinds of glacial deposits.

In addition, curiosity kicks in: What must the area have looked like? How fast did the ice move? How many times did it come and go? How did it deposit materials in the sequences we see today? Can our growing understanding of these materials help us predict their depth, character, and occurrence in various places? If so, how can this understanding help us interpret and reconstruct the events of the Great Ice Age and possibly help us predict future climate changes?

### **WHAT GEOLOGISTS OBSERVE ABOUT ICE AGE DEPOSITS**

Recognition that much of the Midwest had been covered by glaciers provided the basis for systematic study of the deposits and landforms left behind by the glaciers. Beginning in the 1860s, Illinois geologists, including A. H. Worthen and Frank Leverett, published comprehensive surveys of the state’s geology. Building upon the observations and studies of these natural scientists, geologists have since



- noted and mapped landforms, including their location, extent, shape, orientation, and relationships to each other,
- described the materials exposed in *outcrops* (such as in road and railroad cuts and creek banks), including their color, *texture* (percentages and distribution of different grain sizes), and vertical sequence from the lowest units to the uppermost that contains the modern soil, especially noting special features such as the remains of buried soils, and
- described the sequence and characteristics of the materials brought to the surface by drilling and, where possible, studied the relationship of the deposits to each other and to bedrock.

As they describe outcrops or drilling samples, geologists take samples and then

- analyze them for percentages of pebbles, cobbles, boulders, and finer material that encloses these larger rocks,
- analyze the types and percentages of minerals in them,
- note any fossils they contain, and
- where possible, make use of modern *radiometric age-dating* techniques to arrive at estimates of actual ages for certain types of sediments and deposits.

## PRINCIPLES AND TECHNIQUES USED TO DECIPHER THE ICE AGE STORY IN ILLINOIS

In the last chapter we saw how just observing the landforms and earth materials on today's landscape can tell us much about the existence of glaciers in Illinois. Geologists also make use of well-established principles and many sophisticated scientific techniques to learn more about glacial deposits. The most important of these principles and techniques are described below.

### Age Dating

Geologists need to understand as much as possible about the rates at which geologic processes occur in order to assess the impacts these processes may have on human activities. For example, landslides may occur quickly, as a sudden slump or fall of blocks of rock or glacially deposited material, or as a slow creep of saturated soil down a slope. Rates of stream and wave erosion in different kinds of geologic materials help us determine whether to build in certain areas, or what kinds of protective structures or techniques we can use to help reduce damage to structures already built. Knowing something about rates of soil formation and rates of wind erosion of soil helps us plan for wise conservation of this valuable resource. Many geologic processes take place very slowly, including the advance and melting of glaciers. Techniques have been developed that help us understand the ages when various materials were deposited by the glaciers visiting Illinois, and the rates at which these materials were deposited.

**Relative age dating** One of the basic principles geologists use to determine the ages of rocks and sediments relative to each other is the law of superposition, which states that in any undisturbed sequence of sedimentary *beds*, or deposits, the bed at the bottom of the sequence was deposited first and is the oldest, and the bed at the top of the sequence was

deposited last and is the youngest. Therefore, in a sequence of undisturbed glacial materials overlying bedrock, the one lying directly on the bedrock surface was deposited first, and each succeeding layer is younger than the one below. The youngest layer lies at the top and was the last to be deposited.

As an example of relative age dating that can reveal the history of a series of beds, let's consider an outcrop where a bed of clay and silt underlies a glacial till, and above the till is a sand. We see no evidence that these sediments have been disturbed. From the clay and silt we can infer that a lake once covered the site. A glacier then advanced across the landscape and deposited the till. After the glacier retreated, sand was deposited, perhaps as a beach at the shore of a lake or as river *alluvium*.

**Radiometric age dating** In contrast to relative age dating, which tells us only that a layer of sediment or rock is older or younger than adjacent layers, radiometric age dating (an age expressed in years and calculated from the quantitative determination of radioactive elements and their decay products) allows us to say with a degree of certainty how old a layer of sediment or rock actually is. One of the most useful techniques for dating Ice Age events taking place in about the last 50,000 years is the well-known carbon-14 dating method. Carbon-14 dating is based on the known, fixed decay rate of carbon-14, a radioactive element that naturally occurs in the atmosphere. All living things contain carbon-14 in the same concentration as in the atmosphere. When the plant or animal dies, the exchange of carbon-14 with the atmosphere ceases, but the radioactive carbon-14 in the dead organism continues to decay. By measuring the amount of carbon-14 left in the wood, shell, peat, or bone, the age of the material and of the enclosing sediment can be determined.

Other techniques not commonly used in Illinois, such as studying reversals of the earth's magnetic field, have been used elsewhere to assign approximate ages to older glacial sediments. Through regional *correlation* with Illinois' glacial deposits, some of our older glacial materials can be dated. Further information on radiometric age-dating techniques, magnetic reversals, plate tectonics, and related topics can be found in geology textbooks.

## Drilling

During the years that Illinois has been settled, tens of thousands of wells have been drilled into glacial drift to search for water or simply to find out what is below ground. Depending on the needs of the client, drillers record, to the best of their ability, the types of earth materials encountered and, in some instances, collect samples of the materials for study. Even though a drillhole can be likened to a mere pinprick on the broad surface area of Illinois, the records (logs) and samples from these holes provide a wealth of detailed information about what is beneath our feet. This invaluable information can be obtained in no other way.

**Lithologic and mineralogical analysis** By analyzing the composition of sediment left by the glaciers and recovered from outcrops and drillholes, geologists can usually determine the general path traveled by the ice. For example, because tills may contain igneous, sedimentary, and metamorphic pebbles similar to those that occur at the bedrock surface in parts of Canada and states to the north, the paths traveled by the ice can sometimes be traced back to areas in the north where these rock types crop

out at the land surface. Also, by comparing the ratios of limestone to *dolomite* pebbles in the tills, and knowing that limestone composes much of the bedrock to the northwest of Illinois whereas dolomite predominates to the northeast, geologists can conclude that tills with greater amounts of limestone pebbles were probably deposited by glaciers originating from the northwest, and tills with greater amounts of dolomite pebbles were probably deposited by glaciers originating from the northeast.

Similarly, by determining the types of minerals in the clay portion of tills, and knowing where shale (a type of bedrock) that contains similar clay minerals occurs, geologists can determine the general areas traversed by the ice. For example, older tills in western Illinois contain significant amounts of a group of clay minerals that expand when wet; so does Cretaceous and younger bedrock in western Iowa and Minnesota and eastern parts of North and South Dakota. Geologists can conclude, therefore, that these older tills in western Illinois were deposited by a glacier that originated in central Canada and took a southeastward path into the Midwest and western Illinois (see fig. 2). In contrast, clayey tills in northeastern and east-central Illinois contain a great deal of the clay mineral called illite (named for the state of Illinois). The shale bedrock of the Lake Michigan region and areas to the northeast contains a great deal of illite. Therefore, we can infer that these clayey tills were deposited by glaciers that traversed these northern and northeastern areas.

Sometimes the *fabric* of a till—the orientation of pebbles and cobbles within it—can tell us the direction the glacier came from. Oblong pebbles and cobbles tend to be deposited with their long axes parallel to the direction of ice movement. Usually this orientation parallels the bedrock glacial striations, which also indicate the direction the glacier moved. The orientation of these pebbles and cobbles can therefore be used to determine the direction of ice movement even where striations on rock surfaces are absent.

**Buried soils** In many places we can see the remains of a soil buried within a sequence of layers of glacial sediment. Soils develop very slowly as geologic materials are exposed to *weathering*. Therefore, the most important thing about buried soils is that they record a climatic warm period between glacial cold periods. Sometimes the characteristics of the soil itself and any plant remains it contains can also tell us about the interglacial climate. And, of course, by using the principles of relative age dating, we know that the material in which the soil has developed is older than any overlying sediments and younger than any underlying ones.

## PUTTING IT ALL TOGETHER

Early in the history of glacial studies in Illinois, geologists placed almost exclusive emphasis on describing landforms and interpreting the processes of glaciation on the basis of these landforms. Many interpretations were also made from the materials exposed in outcrops. Later, as the value of subsurface (below the ground surface) information became more apparent and methods of analysis became more sophisticated, a more complete picture of the Ice Age in Illinois emerged. The multitude of individual observations and analyses, considered independently, tell only about the individual sites described. However, geologists soon realized that the earth materials at one outcrop were similar to those they had described at another and that vertical sequences of materials at one location



were repeated elsewhere, often with only minor differences. It was then a short step to compiling and organizing these observations and information from various locations into a coherent story that explained Ice Age materials in Illinois. New facts, observations, and techniques continually improve this understanding.

## **HOW GEOLOGISTS PRESENT THE CURRENT UNDERSTANDING OF GLACIAL DEPOSITS**

Geologists compile and present their observations and data in horizontal and vertical formats to tell the story of glaciation in Illinois. Geologic maps show the horizontal occurrence and extent (the *areal* distribution) of various kinds of geologic units across the landscape (fig. 17). Cross sections show the vertical sequence, extent, thickness, shape, and relationships of geologic units from the ground surface down to some arbitrary depth (fig. 18).

### **GEOLOGIC MAPPING OF ICE AGE DEPOSITS HELPS LOCATE WATER SUPPLIES**

Over the years, many geologists at the Illinois State Geological Survey studying groundwater resources have responded to requests for information about developing groundwater supplies for homes, farms, industries, and towns. Because much of the state is covered by Ice Age deposits and the bedrock that underlies large areas of the state yields little or no water, a knowledge of the water-yielding characteristics of the glacial deposits is extremely important.




For example, when an ISGS geologist receives a request for information to help a new homeowner in a rural area develop a groundwater supply, and has to reply that there are no known sources of water at that new home site, the geologist begins to realize how important it is to be able to predict the distribution of water-yielding deposits. Within the glacial deposits, the principal sources of water (aquifers) are the layers of sand and gravel that were deposited by the meltwaters of the glaciers. These deposits are often buried within or below pebbly clay tills. Anyone who has dug a shallow hole in beach sand on the shore of a lake knows that water moves very rapidly into that hole once you reach the water level of the lake.

Similarly, the new homeowner is looking for a sand and gravel deposit that allows water to move rapidly from the deposit into a well. When no sand and gravel deposits are present and the bedrock does not yield water, the homeowner may have to rely on hauling water or on constructing a large-diameter well in the clayey glacial deposits through which water moves only very slowly. The large well diameter allows for a large amount of water to collect over a long period of time to meet the home's most minimal needs.

If people purchasing properties in rural areas can consult maps that show the thickness, depth, and extent of sand and gravel bodies in the area they are interested in, they would certainly be more likely to choose an area for building a house where they could get water from sands and gravels rather than choose an area where the geology shows that water-yielding deposits are unlikely to be present. The same could be said for selecting a site for a new development or industry.



Detailed mapping of the glacial deposits in Illinois, therefore, is a very important mission of the Illinois State Geological Survey. —John P. Kempton

### Wisconsin Episode and later



-  River sediment and dune and beach sand
-  Fine grained lake sediment
-  Thickness of silt deposited as loess (5 ft contour interval)

### Wisconsin Episode


Till and ice-marginal sediment

-  End moraine
-  Ground moraine


### Illinois Episode

-  Till and ice-marginal sediment
-  Sorted sediments including river and lake deposits and windblown sand

### Pre-Illinois episodes

-  Predominantly till and ice-marginal sediment

### Bedrock

-  Mostly Paleozoic shale, limestone, dolomite, or sandstone; exposed or covered by loess and/or residuum

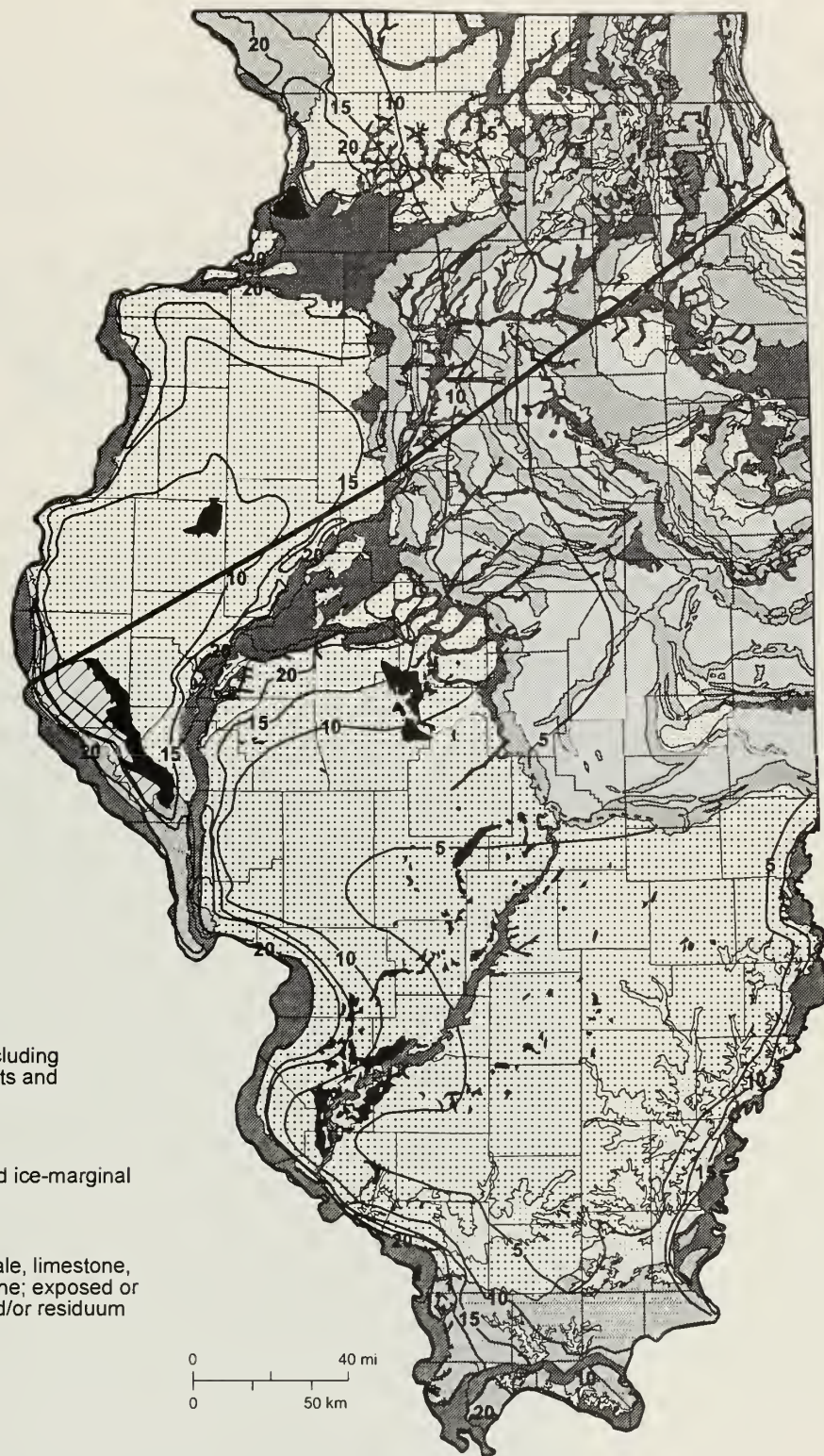
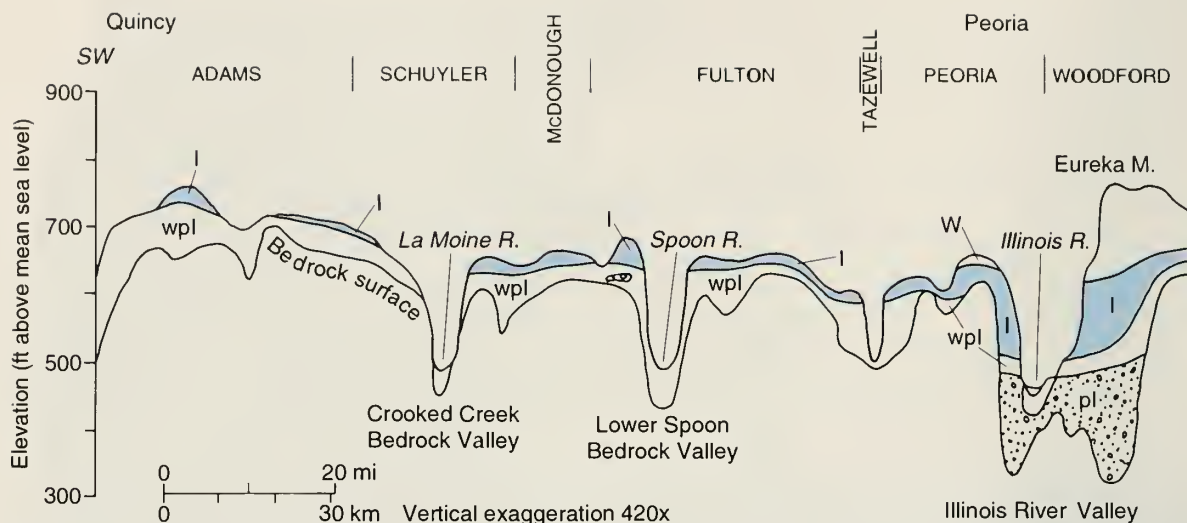


Figure 17 This geologic map shows the horizontal extent of the rock and earth materials at the surface in Illinois. Line of the cross section in figure 18 is shown.





**Figure 18** This cross section shows in a general way the vertical succession of pre-Illinois, Illinois, and Wisconsin Episode deposits in the subsurface along a line from Quincy on the west through Peoria to Chicago on the east.

### HOW TO READ A CROSS SECTION

Because there are many reasons why we need to know what is beneath the ground surface—searching for water and mineral resources and siting waste disposal facilities, among others—geologists construct cross sections to show what is known about the vertical sequence and lateral extent of rocks and sediment across the area of interest. This area may be as small as a local factory site where the rate and direction of flow of some contamination infiltrating into the ground must be determined for clean-up, or it may be as large as a state or even several states in order to achieve a regional picture of the extent and variability of major subsurface rock and sediment units. Cross sections are critical for interpreting the relationships among the various layers of sediment deposited across an area.

A cross section is a profile of a vertical section of the earth. It provides the necessary third dimension for visualizing and understanding the distribution of the layers below the ground surface.

The vertical and horizontal dimensions on this cross section are drawn to different scales. The scale of a map indicates the proportion (expressed as a fraction or ratio) between the distance on the map and the corresponding actual distance of the land being mapped; for example, 1 inch on a map may correspond to several hundred feet, a mile, or tens of miles of actual distance. On the cross section in figure 18, the scale bar indicates that 1 inch represents about 23.5 miles of actual distance.

Because the landscape in the Midwest is comparatively flat, if the vertical scale of a map were the same as the horizontal scale, the hills





and valleys would appear as only very shallow bumps and dips, and the underlying strata could hardly be seen at all. In order that landscape features and subsurface strata can be recognized, the vertical scale is often considerably exaggerated.

Figure 18 shows a generalized southwest-to-northeast cross section from Quincy to Peoria to Chicago. Perhaps the most striking feature of the cross section is that both the landscape and the bedrock surface are shown with steep slopes, deep valleys, and nearly vertical valley walls. The Illinois landscape across this area is definitely not this rugged.

These apparent steep features are the result of intentional vertical exaggeration. On the cross section, 1 inch in the vertical direction represents almost 300 feet, whereas 1 inch in the horizontal direction represents about 23.5 miles. Thus the vertical scale exaggerates the features of the landscape in order to show the layers of glacial sediments lying between the bedrock surface and the ground surface.

One can also easily notice the following features: (1) till and other fine textured sediments predominate in the glacial cover over the bedrock; (2) most of the sand and gravel occurs in the deeper bedrock valleys; (3) the glacial cover is, in general, thicker between Peoria and Chicago than it is between Quincy and Peoria; (4) most of the additional thickness is due to deposits left during the last glaciation; (5) the bulk of the glacial sediment from Quincy to Peoria consists of pre-Illinoian deposits with a comparatively thin cover of Illinoian sediment; (6) Illinoian glacial deposits disappear toward Chicago; and (7) sediments of the Wisconsin glaciation directly overlie bedrock in eastern Illinois and the Chicago area.

— Myrna M. Killey

In addition, geologists take the vast array of data that has been collected over the decades from many sites in many states and assemble it into tables to support generalizations and conclusions for further research and publication. Such tables may collect data about grain size, clay mineral composition, pebble orientation, and pollen percentages.

Altogether, over a hundred years' worth of geological investigations has revealed a great deal about the Ice Age in Illinois. We know (1) about the landscape that existed before the glaciers came, (2) the areas covered by the different glaciers, (3) the soils that developed during warm periods between advances of the continental ice sheets, and (4) the ways the glaciers deposited materials and created the landforms we see today.

### **EVIDENCE FOR MULTIPLE ICE ADVANCES DURING THE ICE AGE**

Once the glacial origin of sediments in northern areas of North America and Europe was accepted, geologists quickly recognized that within these sediments were beds of plant remains, wood, and other organic deposits, as well as recognizable remains of soil horizons similar to those found in modern soils today. Geologists also found buried fossils, including shells, bones, and teeth of animals now extinct. All such discoveries pointed to warmer and glacier-free periods. As more and more places containing zones of weathering, old soils, and organic material were discovered within the sequence of glacial sediments, it became obvious that there had been many ice advances, each separated by a warming period during which soils formed and plants and animals lived on the land surface.

As these nonglacial intervals were traced across broad areas of North America, a fourfold subdivision of continental glaciation was recognized. The subdivisions were named Nebraskan (the oldest), Kansan, Illinoian, and Wisconsin (the youngest) after the states in which they were first described. The three warm intervals separating the four glaciations were called the Aftonian, Yarmouth, and Sangamon interglacial intervals, again named after places where they were first recognized or studied. As a result, during much of this century, the concept of four major glaciations and three major interglacial intervals was commonly accepted.

In the last two or three decades, however, a growing body of information, based on more extensive work on continental glacial deposits and on deep-sea coring of ocean sediments, has led to the recognition that there were in fact more than four glaciations. Much current research now focuses on relating evidence from ocean cores to the study of glacial sediments on the land to more clearly understand the number, timing, and extent of ice advances.

—John P. Kempton

## THE LANDSCAPE BEFORE THE GREAT ICE AGE

*Imagine exploring Illinois before the Ice Age. You would have roamed a landscape far different from today's. You would find hills and valleys, plateaus, and large rivers flowing westward through central Illinois and southward through north-central Illinois. Wouldn't it be fascinating to be able to take a picture of that ancient land surface as it really appeared, and compare it to the surface that geologists today have portrayed through painstaking compilation of thousands of bedrock elevations from drill cores and samples?*

### INVESTIGATING BEDROCK IN ILLINOIS TODAY

In Illinois and much of the Midwest, the term "bedrock" refers to the solid rock buried beneath the *unlithified* sediment of glacial origin. Is the bedrock a flat surface composed of one type of rock? Or were there hills and valleys on a buried surface consisting of several different types of rock? How do we find out?

The first step in investigating the bedrock is to go to places in Illinois where bedrock is exposed. Bedrock occurs at or very close to the ground surface in three areas of Illinois—the northwestern corner (Jo Daviess, Stephenson, and Carroll Counties), western Illinois (Adams, Pike, and Calhoun Counties), and the southern part of the state (fig. 17). We have little difficulty believing that the landscape before glaciation in these areas probably looked similar to the way it does today. Elsewhere in the state, where the cover of glacial drift is thin, bedrock can also be seen in some roadcuts, in the bottoms and banks of streams, and where the overlying glacial cover has been removed by erosion.

Most of the rest of Illinois, however, is mantled by glacial sediment ranging up to several hundred feet thick, and we might think there is little we could find out about the pre-Ice Age landscape. Over the years, however, many thousands of holes have been drilled through the glacial drift into bedrock in the search for water, oil, coal, and other resources or just to gather more detail for mapping. The records, or logs, of earth materials encountered in these drillholes provide the next step in investigating bedrock. Drillers' logs tell us about both the types of bedrock that underlie the glacial drift and their elevations above mean sea level (msl). By plotting the elevations of the buried bedrock surface, geologists have been able to assemble a fairly complete picture of the landscape before the glaciers came (fig. 19).

### KINDS OF BEDROCK BENEATH THE GLACIAL DRIFT

Evidence from the thousands of holes that have been drilled deep into bedrock tells us that beneath the glacial drift many layers of sedimentary rocks from 2,000 to about 15,000 feet thick overlie a "basement" of ancient igneous and metamorphic rocks, mainly granite. These basement rocks





**Figure 19** This shaded relief map shows the shape (topography) of the bedrock surface in Illinois. Compare with figure 26.

extend deep into the earth's crust. None of them are exposed at the ground surface or even found at the bedrock surface anywhere in Illinois, although they can be seen in the Missouri Ozarks and in central Wisconsin.

The overlying sedimentary rocks, mainly shale, sandstone, limestone, coal, and dolomite (fig. 20), range in age from about 510 million (Cambrian) to 290 million years old (Pennsylvanian) (table 1). Pennsylvanian-age rocks are the youngest bedrock across most of the state. The sediments from which these rocks were formed were deposited in and near ancient seas whose margins fluctuated across what is now known as Illinois. Over time, the sediments were gradually lithified by compaction and cementation. Later, Cretaceous gravels about 100 to 66 million years old were deposited in extreme southern and western Illinois as part of an *embayment* (a deep indentation or recess of a shoreline forming a bay) that extended all the way from the present-day Gulf of Mexico to the southernmost tip of Illinois. Cretaceous sands deposited in a delta overlie the gravels. During Tertiary time, between about 66.4 and 1.6 million years ago, coastal plain and deltaic sediments were deposited at the extreme southwestern tip of the state.

## THE BEDROCK LANDSCAPE

Except for localized areas where glacial ice scoured the bedrock surface, this surface topography was primarily shaped by erosion by rivers. A very long time intervened between deposition of Pennsylvanian-age sediments (approximately 286 million years ago) and deposition of Ice Age sediments beginning about 1.6 million years ago (table 1). If other sediments were deposited during this time, they have been eroded away, and no physical record of them remains. We must assume that erosion was the dominant process that affected the preglacial landscape during those nearly 285 million years. As with today's landscape, the bedrock surface can generally be divided into uplands and valleys.

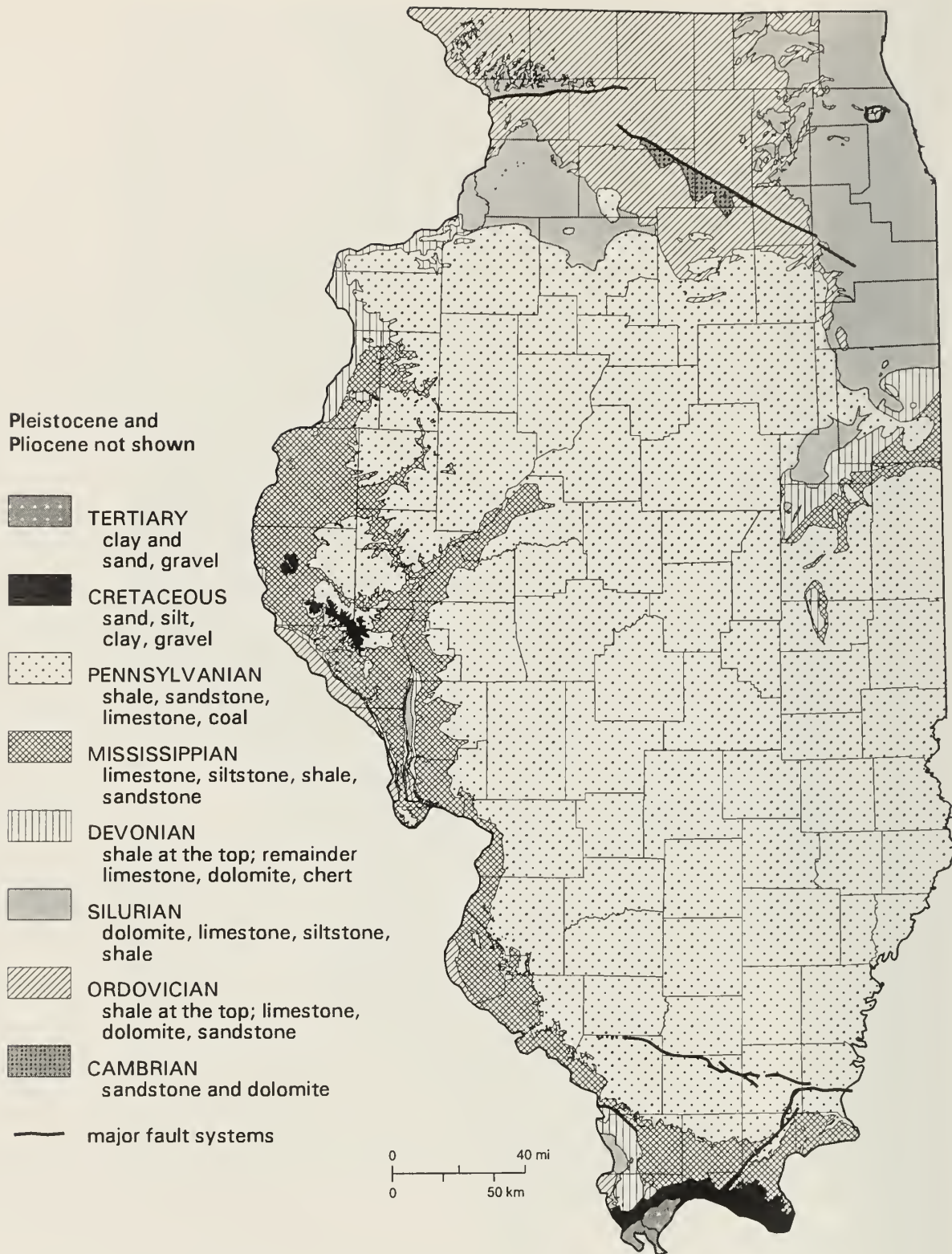
### Bedrock Uplands

Great mountain ranges of folded and faulted (broken) rocks never existed in Illinois in the distant geologic past, according to all available evidence. Sedimentary rocks that were fairly resistant to erosion, such as limestone, dolomite, and sandstone (fig. 20), form *cuestas* and uplands, especially in the northeastern, northwestern, western, and far southern parts of the state. The highest parts of the preglacial bedrock surface are still exposed in the state's northwestern corner and in the Shawnee Hills of southern Illinois (fig. 19). Here, the elevation of the bedrock surface is about 800 to more than 1,000 feet above msl. In western and northeastern Illinois, where bedrock is also dominated by limestone, sandstone, and dolomite, bedrock surface elevations of 600 to 800 feet above msl are common. Over much of the rest of the state, Pennsylvanian shale forms the bedrock surface. It was easily eroded and resulted in extensive areas of low bedrock elevations, ranging from 400 to 600 feet above msl over much of the southern two-thirds of the state.

### Bedrock Valleys

Considering the vast amount of time during which the bedrock surface was exposed to erosion, it is not surprising that a major drainage system developed on the preglacial landscape. One of the most striking features





**Figure 20** This geologic map shows the types of rocks that occur at the bedrock surface in Illinois.



on this landscape is a large valley system in central and east-central Illinois (fig. 19). This valley, called the Mahomet Bedrock Valley, enters the state from west-central Indiana and meanders westward to join the Ancient Mississippi Bedrock Valley in the vicinity of Tazewell and Mason Counties. Generally these two valleys lie between 200 and 400 feet above msl. Much of the drainage of the continental interior converged into these and other major preglacial valleys in Illinois, then entered the embayment that extended from the southernmost tip of Illinois to the present-day Gulf of Mexico. The Cretaceous and Tertiary sediments at the southern tip of the state (fig. 20) reflect the northernmost extent of this embayment.

Other major drainageways on the bedrock surface include the Ancient Iowa River (the present Mississippi valley from the west end of Rock Island County to the mouth of the Illinois) and tributaries to the Mahomet Bedrock Valley or the Ancient Mississippi Bedrock Valley. Most of these drainageways also occur at elevations between 200 and 400 feet above msl. Parts of the bedrock valleys coincide with present-day river valleys and have been reoccupied by today's rivers, such as the lower Illinois and Kaskaskia Rivers.

These well-established ancient drainage systems were disrupted at various times and in various ways by the repeated advances of continental glaciers. These disruptions will be discussed in following chapters.

## **THE DRIFTLESS AREA**

Jo Daviess County and parts of Stephenson and Carroll Counties are part of a larger area extending into southwestern Wisconsin, northeastern Iowa, and southeastern Minnesota that is called the Driftless Area because no sediments deposited directly by glaciers have been found to overlie the bedrock in that area (fig. 2). Some evidence suggests that one of the oldest glaciers may have at least partially crossed the area: some high-elevation sand and gravel (outwash) has been found. If till was deposited there, however, it has been eroded or not yet found.

The Driftless Area is a hilly, rugged landscape mantled only by loess and stream alluvium. Its driftless condition seems curious, considering that the drift entirely surrounding this region for many miles in all directions proves that glaciers surrounded the area at one time or another during the Ice Age. However, the bedrock in this area, ranging from about 800 to more than 1,000 feet above msl (fig. 19), is higher than the land surface anywhere else in the state, including areas where glacial drift covers bedrock. Charles Mound, the highest point in the state at an elevation of 1,235 feet above msl, is located in the Driftless Area.

We must conclude that, because glacial ice will seek the path of least resistance as it moves along, it must have been deflected by this high area. Although it is tempting to imagine the area as an island of rock surrounded by ice, it is more likely that ice moved past it from various directions at one time or another during the Ice Age but never completely surrounded it at any one time. Today, this rugged area shows us how other parts of Illinois may have appeared before the glaciers came.

## THE EARLIEST GLACIATIONS

*Imagine standing on the bluffs of the Ancient Mississippi River Valley somewhere between what is now Peoria and Beardstown about 800,000 years ago. You might well have seen the leading edges of two vast continental ice sheets, one advancing out of the northeast and one out of the northwest, facing each other across the broad river valley!*

### WHAT WE KNOW ABOUT THE EARLIEST GLACIATIONS


Early study and classification of glacial deposits and ancient buried soils led geologists to believe that there were four major glaciations in North America during the Great Ice Age: (1) the oldest glaciation, the Nebraskan, was followed by the Aftonian interglacial interval, (2) the second glaciation, the Kansan, was followed by the Yarmouth interglacial interval, (3) the Illinoian glaciation was followed by the Sangamon interglacial interval, and (4) the Wisconsin glaciation was followed by the present warm interval. These glaciations were named after the states where their deposits were first studied or are best exposed. Readers of older publications about Ice Age glaciers will note common usage of the terms Nebraskan, Aftonian, Kansan, and Yarmouthian, as well as the later names. Until the early 1970s, Illinois geologists recognized these classic four subdivisions of the Ice Age.

More recent studies of glacially deposited sediments in North America and Europe, and especially of cores of ocean sediments from the North Atlantic, have revealed a much more complex picture; major glaciations occurred several more times than previously recognized. Many geologists now think that at least seven and perhaps as many as 12 or even 15 continental glaciations occurred before the Illinoian and the Wisconsin glaciations in the continental United States. These estimates are based on several types of investigation, including tracing mineralogical composition and physical characteristics of subsurface glacial sediments recovered from borings from one area to another, careful study of ancient soils that developed in these early glacial deposits, and techniques such as reversed magnetic polarity, amino-acid racemization, and radiometric dating that can help date and correlate sediments from one place to another.

Because much work remains to be done to identify, characterize, and trace these early glacial sediments, they are not given formal names and are grouped together. Because they were all deposited before the Illinoian glaciation, these sediments are often referred to as pre-Illinoian sediments (table 2). When they have been characterized, dated, and traced more precisely, these sediments will be correlated with sediments of similar ages elsewhere and assigned specific *lithostratigraphic* names.

The sediments deposited by the first glaciers to enter Illinois have been severely eroded by running water and more recent glaciers, so that today

**Table 2** This timetable illustrates the glacial and interglacial events, sediment record, and dominant climate conditions of the Ice Age in Illinois.

Years before present	Time-distance diagram Interglacial and glacial episodes	Sediment record	Dominant climate conditions Dominant land forming and soil forming events
HOLO-CENE	interglacial episode	River, lake, wind, and slope deposits.	Warm; stable landscape conditions. Formation of modern soil; running water, lake, wind, and slope processes.
10,000	 <p>WISCONSIN (late) glacial episode</p> <p>glacial ice</p>	Till and ice-marginal deposits; outwash and glacial lake deposits; loess.	Cold; unstable landscape conditions. Glacial deposition, erosion, and landforming processes (e.g., formation of end moraines, outwash plains, valley trains, proglacial lakes, kettles), plus running water, lake, wind, and slope processes.
25,000		Loess; river, lake, and slope deposits.	Cool; stable. Weathering, soil formation (Farmdale Soil and minor soils); wind and running water processes.
75,000	WISCONSIN (early and middle) glacial margin north of Illinois	River, lake, wind, and slope deposits.	Warm; stable. Weathering, soil formation (Sangamon Soil ); running water, lake, wind, and slope processes.
125,000	SANGAMON interglacial episode	Till and ice-marginal deposits; outwash and glacial lake deposits; loess.	Cold; unstable. Glacial deposition, erosion, and land forming processes, plus proglacial running water, lake, wind, and slope processes; possible minor soil formation.
300,000	ILLINOIS glacial episode	River, lake, wind, and slope deposits.	Warm; stable. Long weathering interval with deep soil formation (Yarmouth Soil); running water, lake, wind, and slope processes.
425,000	YARMOUTH interglacial episode	Till and ice-marginal deposits; outwash and glacial lake deposits; loess plus nonglacial river, lake, wind, and slope deposits.	Alternating stable and unstable intervals of uncertain duration. Glacial deposition, erosion, and landforming processes, plus proglacial and interglacial running water, lake, wind, and slope processes; interglacial weathering and soil formation.
1,600,000 and older	<p>?</p> <p>PRE-ILLINOIS glacial and</p> <p>?</p> <p>interglacial episodes</p>		



only scattered remnants of these sediments remain, generally buried beneath younger deposits. Therefore, it is much more difficult to learn about these earliest glaciations than about the later Illinoian and Wisconsin glaciations. No known landforms composed of glacial sediments older than those of the Illinois Episode have been identified to date, although future mapping of these old deposits may show some evidence of such features.

## SOURCE AREAS OF THE EARLY GLACIERS

In the absence of evidence such as distinctive lobe-shaped moraines that can indicate the direction of ice advance, we must rely directly on the sediments themselves to learn where the glaciers came from. In the deposits of these earliest Ice Age visitors we find evidence for both northeastern and northwestern source areas (fig. 2; fig. 21, no. 2).

### Northwestern-Source Glaciers

In a strip of western Illinois approximately 70 miles long (from Hancock County on the north to Pike County on the south) and from 2 to about 15 miles wide (from the Mississippi River bluffs eastward), pre-Illinoian sediments occur directly beneath the loess that blankets the land surface. The proximity of these sediments to the surface means they are generally more easily studied here than elsewhere. By means of samples taken from outcrops and drillholes, geologists can trace these sediments from outcrops in this strip beneath younger deposits to the east. If these glaciers had a northwestern source area, they must have crossed Iowa before

## HOW GEOLOGISTS CLASSIFY AND NAME ICE AGE DEPOSITS AND TIME

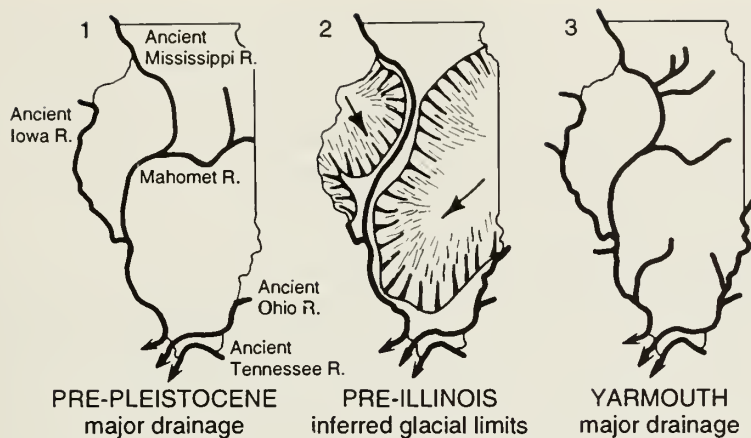
Over the years, geologists have developed sets of terms to classify rocks and sediments. These classification systems help people communicate when discussing geologic history or referring to specific layers of rock and sediment (called *strata*). Because our understanding of geologic strata grows as new data become available and new ideas and techniques develop, classification systems are continually being modified. Commissions of geologists periodically review and modify the guidelines (called *stratigraphic codes*) for classifying geologic strata and time.

**Strata** Geologists describe the *lithologic* (physical) characteristics of strata that allow them to be mapped and traced regionally. A unit is named after a place where it is well exposed and the lithologic characteristics are typical (the “type locality”). For example, the Kankakee Formation (a bedrock formation) was named for the Kankakee River near the city of Kankakee, where the strata of the typical dolomite lithology crop out in the river

banks. Such units are known as *lithostratigraphic units*. The basic unit in lithostratigraphic classification is the *formation*, which must be identifiable on the basis of easily recognized physical properties and must be widespread and thick enough to be mappable on a regional scale. A formation may be subdivided into smaller units called *members*, and several formations can be combined into larger units, called *groups*.

**Geologic time** Similarly, geologists have subdivided geologic time into various named intervals that are useful in discussing geologic history. For example, the Pleistocene Epoch (or Great Ice Age) is part of the Quaternary Period and is subdivided into smaller intervals, such as the Illinoian and Wisconsinan Ages, which are represented by deposits of different major glaciations.

Originally, the sediments of the Ice Age were not classified in the same way as bedrock. That is, formations and members of glacial sediments were not named. Instead, geologists named the major glaciations after the states (Kansas, Nebraska, Illinois, and



**Figure 21** The extent of pre-Illinois Episode glaciations and interglacial drainage in Illinois is shown in this series of small maps. See table 2 for approximate times of glacial and interglacial intervals.

entering Illinois. Iowa geologists have determined that correlative deposits in their state have a predictable sequence, consisting of two distinct bundles of tills. The older, underlying bundle of tills has been named the Alburnett Formation, and the younger, overlying bundle has been named the Wolf Creek Formation. These deposits in the same sequence have been traced from Iowa across the Mississippi River and western Illinois nearly

Wisconsin) where deposits of those glaciations were well exposed. Endings of “-an” were added to the state names (except Wisconsin) when referring to the associated time, sediments, landforms, or the glaciations themselves. Between 1960 and 1970, geologists from Illinois were among the first to classify the Ice Age deposits into formations and members. They also subdivided the Quaternary Period into glacial and interglacial ages and subages on the basis of glacial and interglacial deposits, and applied adjectival endings to all these units (for example, Illinoian Age, Sangamonian Age, and Wisconsinian Age).

**New time classification** In the most recent stratigraphic code, geologists provided new guidelines for subdividing geologic time in cases where the sediment units on which the time is based are clearly time-transgressive, that is, when deposition of a single distinctive unit clearly began and ended earlier in one place than another (see sidebar, p. 48). Such is the case with most glacial and interglacial units. With radiometric age-dating, we can document that the last glaciati

on in Canada than it did in Illinois. Similarly, we can document that it ended in Illinois before it did in Canada. Recently geologists have introduced a modified classification system for Quaternary time, in which glacial and interglacial intervals are referred to as episodes rather than ages. Episodes are sometimes subdivided into smaller intervals called subepisodes and phases. Unlike most time units in the present system, those in the new system do not have adjectival endings.

#### Alternative Time Systems

Wisconsinian Age	Wisconsin Episode
Sangamonian Age	Sangamon Episode
Illinoian Age	Illinois Episode
Yarmouthian Age	Yarmouth Episode
pre-Illinoian ages	early glacial episodes

This booklet uses the new terminology for classifying Quaternary time. But, if you should read somewhere about the Wisconsinian Age of glaciati

—Ardith K. Hansel and John P. Kempton

to the Illinois River (fig. 18). There is no specific evidence as yet that the northwestern-source glaciers crossed the Illinois River Valley.

Sediments from glaciers from the northwest are distinguished by a great deal of ground-up limestone (a rock composed of the mineral calcite that reacts readily with dilute hydrochloric acid) and low amounts of the clay mineral illite. This contrasts with the mineralogical composition of sediments from glaciers from the northeast.

### **Northeastern-Source Glaciers**

Although deposits of early northeastern-source glaciers have been eroded away in many parts of the state, they can be found deeply buried throughout parts of central and east-central Illinois, especially in some of the deeper bedrock valleys. Over the past 40 years, geologists have studied samples from thousands of drillholes that reached bedrock and have traced and correlated these earliest glacial sediments over broad areas. In a few places where bedrock is comparatively near the surface, such as in Vermilion County, pre-Illinoian deposits have actually been exposed in coal strip mines, such as in Kickapoo State Park.

As mentioned above, northeastern-source sediments generally have a mineralogical composition different from northwestern-source sediments. Pre-Illinoian tills in eastern Illinois (fig. 18) generally contain more ground-up dolomite and dolomite pebbles than ground-up limestone and limestone pebbles. One till in eastern Illinois, however, is unique among the tills with a northeastern source. It is a distinctive deep reddish brown color and contains so much ground-up limestone that it reacts more strongly than other northeastern-source tills when a drop of dilute hydrochloric acid is placed on it. This till is thought to have been deposited by a glacier advancing out of a source farther to the northeast and east than the Lake Michigan basin area, possibly out of the Lake Erie area, in which case it would have ground up some of the limestone bedrock traversed between there and eastern Illinois. The position of this distinctive till in the sequence of pre-Illinoian deposits in east-central Illinois is relatively well known so that when it is encountered, other tills above and below it can be identified and correlated according to their relative age and characteristics.

### **RELATIONSHIP BETWEEN THE PRE-ILLINOIAN DEPOSITS OF EASTERN AND WESTERN ILLINOIS**

We do not yet have the means to tell whether glaciers entered Illinois from the northwest and from the northeast at the same time. We cannot date these sediments because the most commonly used radiometric age-dating technique, carbon-14 dating, does not reach back far enough in time, and other techniques may not be precise enough. Nor does there appear to be any evidence that the tills of western Illinois are found in eastern Illinois or can be correlated to any tills there. So far, then, we do not know the time relationships between the pre-Illinoian eastern and western tills.

### **SEDIMENTS OTHER THAN TILLS**

Our discussion of early glaciations has focused almost exclusively on tills because where we find till, we know that ice once covered that area. Tills are also widespread and are the type of glacial deposit most easily traced and correlated by means of their texture and mineralogical composition.



Nevertheless, logs of drillholes through glacial sediments record many beds of silt, clay, and sand and gravel interspersed within and between layers of till, as well as thick deposits of sand and gravel filling many parts of the bedrock valleys. These sediments indicate that meltwater sorted and deposited rock debris; coarser material was dropped closer to the ice front and finer debris was carried farther away. Where we find sand and gravel within tills, we can hypothesize that it was deposited in a meltwater stream beneath the ice or in a crevasse or by some similar process. Today, these sands and gravels are of great importance because they are commonly saturated with water and can serve as aquifers that supply drinking water for communities, industries, and individual farms and households.

Deposits of sand and gravel generally do not have distinctive characteristics that can be correlated over long distances. However, experience has shown that if the tills above and below major sand and gravel beds can be traced and correlated from one region to another, the occurrence of major deposits of sand and gravel lying between these tills can generally be predicted, and drilling for water can be guided by this information. Locally, some sands and gravels may display certain characteristics, such as grains of a certain mineral, that can be used to correlate these bodies over short distances.

Undoubtedly, the most significant aspect of pre-Illinoian sands and gravels is their thickness and extent in the major bedrock valleys and, consequently, their usefulness as sources for major water supplies for communities located nearby. Perhaps the best-known example is the Mahomet Bedrock Valley, probably formed and occupied by a series of preglacial rivers and glacial meltwater streams (fig. 21, nos. 1 and 3). Up to 150 feet of sand and gravel fill parts of this broad valley. Elsewhere, in the deepest parts of the Ancient Mississippi Bedrock Valley (see figs. 19 and 21, no. 1), a sand with an abundance of distinctive polished pink and red quartz grains occurs. Wherever pre-Illinoian outwash sands containing reddish quartz grains occur, they can probably be correlated to each other, thus providing one more clue to piecing together the story of the earliest glaciations in Illinois.

## **MAJOR RIVER SYSTEMS AFTER THE EARLIEST GLACIATIONS**

After the earliest glaciations (fig. 21, no. 3), the Ancient Mississippi River flowed along the west side of the Driftless Area southward as far as Fulton in Whiteside County. From there, it followed a southeastward course to the present big bend of the Illinois River Valley in Bureau County. With one exception, the river then essentially followed the present course of the Illinois Valley southward to its confluence with the Ancient Iowa River at Grafton in Jersey County. The exception is the present very young valley near Peoria and Pekin, where the Ancient Mississippi Bedrock Valley lies a short distance east of the Peoria-Pekin area. This segment of the bedrock valley is called the Mackinaw Segment, named for the village of Mackinaw that lies above it.

Another ancestral river called the Ancient Iowa River, with headwaters in east-central Iowa, followed the present course of the Mississippi Valley below Muscatine, Iowa, southward to its confluence with the Ancient Mississippi River at what is now Grafton, Calhoun County. Today, its valley is occupied by the modern Mississippi River.

Drilling logs show that the lowest parts of the Mahomet Bedrock Valley and its tributaries are filled with sand and gravel, lake silts, and even a few tills of the earliest glaciers to advance into Illinois. From this evidence, we can deduce that the process of filling in this major valley system began with the earliest glaciers to reach Illinois.

### **THE YARMOUTH SOIL: DISTINGUISHING PRE-ILLINOIAN SEDIMENTS FROM YOUNGER OVERLYING DEPOSITS**

A long interval of warmer climate called the Yarmouth Episode (table 2) occurred after the last of the early ice sheets melted away. The thick soil that developed on the pre-Illinoian deposits has been named the Yarmouth Soil after the village of Yarmouth in Des Moines County, Iowa. Although in many areas this thick soil was at least partially *truncated* (planed off) by later glaciers, what is left can still be seen in outcrops in western Illinois and in samples from drillholes elsewhere in the state. Perhaps the most distinctive parts of the Yarmouth Soil formed where clay and silt slowly accumulated in low, wet, poorly drained areas of the landscape. Today these accumulations of clay and silt are dark gray to black, massive, dense deposits that are called *gley* or *accretion-gley*; in many areas, the Yarmouth gleys are overlain by sediments of later glaciations.

Where the Yarmouth Soil remains complete and was not planed off by later glaciers, it is thick and well developed, about twice as thick as the Sangamon Soil discussed in the next chapter. This fact suggests a lengthy and significant interval of warm climate conditions (table 2).

### **FINDING OUT MORE ABOUT THESE EARLIEST GLACIERS**

Most of our information about pre-Illinoian deposits comes from subsurface samples and logs. Many samples and cores from drilling in western and eastern Illinois have yet to be studied. In addition, excavations for construction of new highways may open up new exposures of glacial sediments to study, and cores from new engineering test holes frequently become available. Whenever and wherever such exposures or borings may occur in the future, geologists will follow to study, describe, sample, and analyze them in order to learn how these new pieces of information fit into the puzzle. As the sediments deposited by early glaciers are more thoroughly studied and their distribution and characteristics become better known, we will indeed learn more about the earliest glaciers to enter the state.

## THE IMPORTANCE OF BURIED SOILS IN STUDYING ICE AGE DEPOSITS

The word *soil* means different things to different people. To the lay person, soil is the material at the ground surface in which plants grow. To the engineer, soil generally refers to all sediments that can be easily differentiated from rock. To the soil scientist, a soil is a sequence of zones of alteration in a sediment or rock (called the parent material). These zones, called *soil horizons*, result from weathering of the parent material. Weathering is exposure to the various chemical, physical, and biological processes that affect geologic materials at and near the earth's surface. The sequence of soil horizons is called the soil profile. The characteristics of the various soil horizons, briefly outlined below, that appear in old buried soils within glacial deposits can provide geologists with important evidence for climatic and other events that occurred as the soil was forming.

The upper part of a soil profile is the most intensively weathered because it is most exposed to surface processes. This top horizon is called the A horizon. It is generally the darkest in color because it contains the largest amount of decomposed organic remains. Below the A horizon in some soils is a subsurface horizon called the E horizon, which has the lightest color in the soil profile because the colored materials have been removed by *leaching*. Leaching is the process by which minerals dissolve in water and are carried downward by infiltrating water from snow and rain into the underlying B horizon. The B horizon is the zone of accumulation of clay particles (sometimes called claypan) carried downward from the A horizon by infiltrating water. The C horizon beneath the B horizon is generally blocky, massive, and only slightly altered from the original sediment or rock. Untouched by weathering processes, the original parent material is called the D horizon. Unweathered rock, in contrast to sediment, is called the R horizon.

Soil horizons were first recognized and studied in the soils existing on today's land surface. When old soils buried within the sequence of glacial sediments were recognized, geologists realized that they could also tell us about events during the Ice Age. Old buried soils tell us that warm intervals occurred between advances of continental glaciers and that the land surface

was stable for a very long time—that is, little erosion took place and no significant amounts of new sediment were deposited.

Often, the buried soil horizons we find are incomplete. This tells us that another continental glacier advanced and overrode the stable land surface represented by this buried soil and sheared off (truncated) part of the soil, leaving only the lower horizons in place. By tracing the overlying and underlying tills across the landscape, we can correlate exposures of an old buried soil from place to place. Some exposures of the soil may reveal a more complete sequence of soil horizons than others, and the most complete sequence tells us most about the nature of the warm interglacial interval during which it formed.

There are many similarities between modern soil and ancient buried soils in Illinois, such as the types and characteristics of soil horizons. From these similarities, we can conclude that the topography and climate under which soils were formed during the warm interglacial intervals were similar to the conditions under which modern soils have formed in Illinois. The thickness of a buried soil and the degree of development of its soil horizons also tell us something about the length of the interglacial interval. Because we know how much time has passed since the retreat of the last ice sheet, we can get an idea of how long an earlier interglacial interval lasted by comparing the depth of alteration of the underlying parent material to the depth of modern soil development.

There are even places where a new soil developed on top of an old soil. For example, in places in western Illinois, we find a very old soil called the Yarmouth Soil, which developed on pre-Illinoian deposits. The Illinoian glacier never overrode the Yarmouth Soil in parts of Adams and Pike Counties, so during the warm interglacial interval that followed the Illinoian glaciation, the Sangamon Soil formed within sediments that had already been altered during formation of the Yarmouth Soil. In some places in the same area, no glacier overrode the Sangamon Soil, so we have modern soil forming in these earlier soils. A soil scientist can tell a great deal about the history of weathering and soil formation in such areas. — Leon R. Follmer



## GLACIATIONS OF THE ILLINOIS AND WISCONSIN EPISODES

*On a clear day about 200,000 years ago, if you had stood atop Bald Knob in Union County at more than 1,000 feet above sea level and looked toward the northeast, you might just barely have been able to see the edge of the Illinois Episode glacier on the horizon! And if, about 20,000 years ago, you had stood near where the tiny hamlet of Oilfield in Clark County is located today and looked northward, you would have seen a low ridge of bluish-gray ice on the horizon, perhaps fading into a lowering dark gray sky to the north. You would have been looking at the front of the Wisconsin Episode ice sheet as it stood at its maximum southward extent. Today, the ridge of higher ground against the horizon you can see from this location is the end moraine of that glacier, composed of till and outwash deposited at the ice margin.*

The evidence of the last two major glaciations in Illinois—the Illinoian and Wisconsin glaciations—is much easier to interpret than that of the earlier glaciations, because the deposits of these glaciations are directly accessible over much of the state, and the landscape left behind can be studied in detail.

### ILLINOIS EPISODE GLACIATION

#### Source Area of the Illinois Episode Glaciers

During the Illinois Episode, ice advanced southwestward out of the Lake Michigan basin from areas in the Great Lakes basin far to the northeast and east. We know the glaciers came from these areas (1) because the tills contain relatively high amounts of the clay mineral illite and the carbonate mineral dolomite, both of which are dominant in the rocks of the Lake Michigan basin area, (2) because of the direction of glacial striations, and (3) by the orientation of rock fragments (called “fabric”) within the tills.

#### Extent of Illinoian Deposits

At the end of the long warm interval called the Yarmouth Episode about 300,000 years ago (table 2), the climate again changed, and a continental ice sheet once more invaded the Midwest. During at least one of the three major advances of the next glacial episode (fig. 22, no. 2), the glacier extended farther south than any other major glacier in the continental United States; at its maximum extent, ice covered nearly 90% of Illinois. For this reason, this episode is called the Illinoian glaciation.

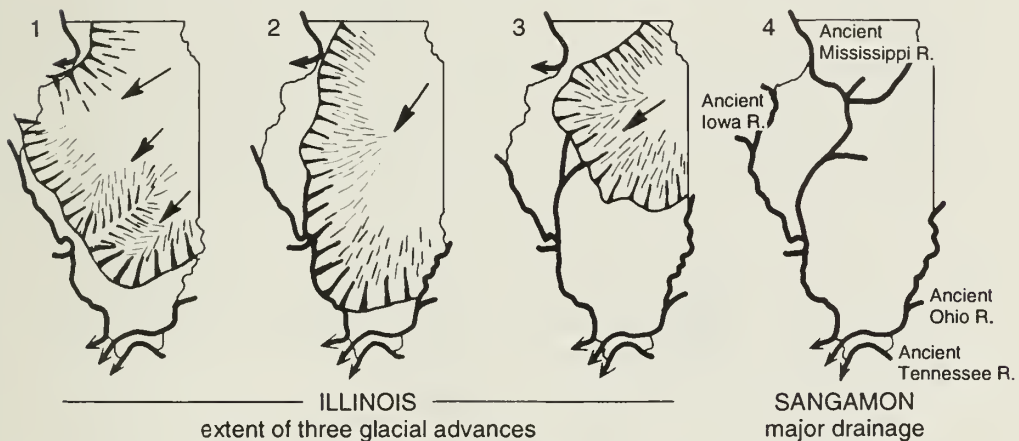
The extent of Illinoian sediments is easily traced because they occur directly beneath the loess that covers most of the state. In the northeastern quadrant of Illinois, however, these glacial deposits are covered by deposits of younger Wisconsin Episode glaciers. Illinoian sediments extend from Stephenson and Winnebago Counties on the Illinois-Wisconsin state line into the southern counties of Jackson, Williamson, Johnson, Saline,

and Gallatin (fig. 17), and from beyond the southeastern border of the state westward across Hancock and Adams Counties and across the Mississippi River.

Over much of the southern part of the state, the Illinoian tills and associated deposits average less than 50 feet thick. The surface of these deposits is usually deeply weathered, and end moraines are not apparent along their southern margin. From these facts, we can speculate that perhaps the glacial deposits extend over such a large area because of a relatively rapid surge of ice that then stagnated and melted in place, rather than because of a continuous flow of ice that brought rock debris to the glacial margin and deposited it in an end moraine. Or the glacier may have stopped where it did only because the climate so far south was warm enough to halt the ice advance, or because the surge of ice no longer possessed enough energy to override the bedrock cuestas of the Shawnee Hills area, which rise to elevations of 600, 800, and even 1,000 feet (fig. 19). Whatever the complete story may be, the great distance covered by Illinoian Episode glaciers remains as impressive evidence of climate extremes during the Ice Age.

### Number of Ice Advances during the Illinois Episode

Deposits of three glacial advances have been recognized in Illinois Episode sediments (fig. 21, nos. 1, 2, and 3) and are classified as members of the Glasford Formation. The first major lobe of ice to push out of the Lake Michigan basin deposited silty tills. The relatively large amounts of expandable clay minerals in these tills reflects the erosion and incorpora-



**Figure 22** The sequence of Illinoian Episode glaciations and interglacial drainage in Illinois is shown in this series of small maps. See table 2 for approximate times of glacial and interglacial intervals.

tion of older loesses, soils, and sediments into the base of the advancing Illinoian Episode ice. It is not yet clear how far south this first lobe advanced, but it reached its maximum western extent in Iowa, crossing the Ancient Mississippi River Valley (fig. 22, no. 1). A brief warm interval of weathering must have occurred after this first Illinoian Episode ice advance because a soil developed in these early deposits, although it is not as deep and widespread as the underlying Yarmouth Soil.

The ice of the second major lobe to enter the state during the Illinois Episode extended almost as far west as the first lobe and reached the southernmost extent in North America of any Ice Age glacier (fig. 22, no. 2). The tills deposited are sandier than those laid down during the first advance. They also have lower amounts of expandable clay minerals and higher amounts of illite, in contrast to the older and younger Illinoian tills. Apparently the ice of this advance also stagnated, or gradually melted in place, because the surface of these sediments is marked by a system of elongate ridges and knolls, consisting largely of sand and gravel, that is known as the "ridged drift" (see below). Only a weakly developed soil is found locally on this surface, suggesting there was a relatively short interval between the middle and late Illinoian glaciations.

The last of the Illinois Episode glaciers to enter the state was not as extensive as either of the first two (fig. 22, no. 3). Only in central and northwestern Illinois do its deposits extend beyond the late Wisconsin Episode glacial boundary, but they can be traced beneath the overlying Wisconsin Episode drift. In general, this latest Illinoian till is more variable in texture. In some areas, the till is fairly sandy; in other areas where the ice overrode lake silts and incorporated them into the till, it is fairly silty. Of the three Illinoian tills, the youngest contains the largest amount of the clay mineral illite.

### **Landscape of the Illinoian Glaciation**

The loess-blanketed deposits of the Illinoian glaciation present a unique landscape known as the Illinoian till plain. In the southern third of Illinois north of the Shawnee Hills area, this till plain is remarkably flat, interrupted only by southeast- or southwest-trending valleys and low ridges. The flatness may be due (1) partly to the fairly low *relief* of the bedrock surface, which ranges from 400 to 600 feet above msl across broad areas (fig. 19), (2) partly to the nature of the ice, which probably behaved somewhat plastically and was mobile enough to fill in low areas and subdue the remaining topography, and (3) partly to the glacier reaching so far south that it melted in place rather than advancing, retreating, and readvancing and thus building up a rolling topography marked by moraines. Another process undoubtedly contributing to the flat till plain is *solifluction* (the slow, viscous, downslope flow of waterlogged sediment and rock debris). The essentially featureless Illinoian till plain contrasts with the sharp ridges, greater relief, and generally uneven topography of the "ridged drift" area discussed below.

Interestingly, the land surface covered by the till of the third Illinois Episode glacial advance (fig. 22, no. 3) has more relief than the surface covered by the older Illinoian tills. For one thing, its margin is locally marked by morainal topography somewhat like the moraines of the later Wisconsin Episode advances. Another reason for its greater relief may be the erosional dissection of the landscape by streams flowing into the Ancient Mississippi Valley during the following Sangamon interglacial episode. Similar erosion by Wisconsin Episode and modern streams draining into the Illinois River drainage system probably also contributed to the greater relief in this area.

**The "Ridged Drift"** An interesting series of features on the southern part of the Illinoian till plain is collectively called the "ridged drift." This extensive complex of ridges and kames is composed of sand, sand



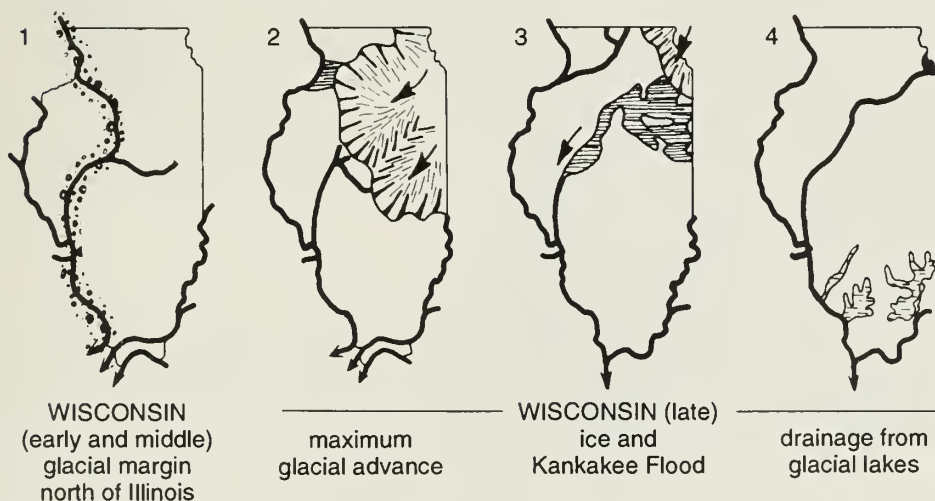
and gravel, silt, and gravelly till that trends northeast–southwest from the boundary of Wisconsin glaciation in Shelby County nearly to the Mississippi River in St. Clair County (fig. 17). The origin of the ridged drift is controversial. The ridges and knolls may have originated as eskers or possibly as infillings of crevasses in the ablating ice by meltwater laden with sand and gravel, forming a series of *kames* and *kame terraces*. Another explanation is that the ice of the second major Illinois Episode advance may have been deflected westward by one or more lobes advancing simultaneously from farther east, possibly out of the Lake Huron basin. In this case, the ridged drift may have been formed in the area between the two ice lobes (called an “interlobate” area) in a complex coalescing of the ice margins. If this was the case, this eastern lobe extended to the present Mississippi River valley from St. Louis southward. The deflected Lake Michigan Lobe spread westward across what is now the Illinois River valley and crossed the present Mississippi River valley into Iowa in the area from Hancock County to Carroll County.

### How Illinoian Glaciation Altered Major River Systems

When the Illinois Episode glaciers reached the bedrock valley near what is now Princeton, Bureau County, the ice dammed the Ancient Mississippi River (fig. 22, nos. 1, 2, and 3). Evidence indicates this diversion was only temporary, however, and meltback of the glacial front permitted the river to resume its former southeastward course (fig. 22, no. 4). This course was occupied until the Wisconsin Episode glacier entered the area (fig. 23, no. 2). By the close of the Illinoian glaciation, the Mahomet Bedrock Valley in east-central Illinois had been completely filled with sediment.

### After the Illinoian Glaciation

Another major interval of warm climate and soil development took place after the last of the Illinoian ice sheets melted away. The soil that developed during this interglacial interval is called the Sangamon Soil after Sangamon County, Illinois, where it was first described (see sidebar, p. 41).



**Figure 23** The sequence of Wisconsin Episode glaciations and interglacial drainage in Illinois. See table 2 for approximate times of glacial and interglacial intervals.

The Sangamon Soil is one of the most thoroughly studied buried soils because it is so widespread. It has been traced westward into the Great Plains region, southwestward to Texas, and eastward to Ohio. In Illinois, it typically shows development of soil horizons, just as modern soil does, and it often has a strong reddish brown color. In poorly drained areas, it exhibits a greenish gray to black, dense, massive, mucky character just as the older Yarmouth Soil does. Although much of the Sangamon Soil in northeastern Illinois was apparently truncated or completely removed by overriding Wisconsin Episode glaciers, elsewhere in the state it is well preserved and serves as an excellent identifiable marker bed where overlain by other sediments such as loesses.

## **GLACIATION OF THE WISCONSIN EPISODE**

In the early and middle parts of the Wisconsin Episode, glaciers did not advance into Illinois; we can deduce this because we find no tills left by these glaciers in Illinois. The only sediments in Illinois from this interval are loesses and river, lake, and slope deposits (mainly silt).

A unique sediment that helps to distinguish Wisconsin Episode sediments from older underlying deposits is a thin, distinct, and widespread organic silt called the Robein silt, which is another marker bed.

The Robein silt is the most widely dated marker bed in Illinois. Samples have generally yielded ages from 28,000 to 25,000 years before present, well within the time of the Wisconsin Episode (table 2). In drilling logs, mention of a black silt or a bed of similar description gives geologists a needed signpost to determine the relative age of sediments above and below it. The Robein silt, in combination with the greenish gray, poorly drained Sangamon Soil on which it rests, provides the unique marker that separates Illinois and Wisconsin Episode deposits both in outcrop and in the subsurface.

## **Source Area of the Wisconsin Episode Glaciers**

The Wisconsin Episode glaciers also entered Illinois out of the Lake Michigan basin, as indicated by northeast–southwest trending striations, the mineralogical composition of the sediments, the fabric of pebbles and cobbles within the tills, and the orientation of the end moraines (fig. 24). The clay mineral illite, found in the shales of the Lake Michigan basin, dominates the clay portion of all the Wisconsin Episode tills, and ground-up dolomite and numerous dolomite pebbles and cobbles from the Silurian-age bedrock in northeastern Illinois also point to the northeast–southwest path taken by the ice.

## **Wisconsin Episode Deposits**

Wisconsin Episode deposits occur at the ground surface in the northeastern quadrant of Illinois, and the margin of these deposits is marked by a prominent end moraine. These sediments, currently assigned to the Wedron Group (formerly formation; see sidebar, p. 36), are exposed in many roadcuts, rock quarries, sand and gravel pits, and creek banks. Because they are comparatively young, these deposits have been only slightly altered by weathering and erosion. These deposits give us the most complete and easily studied clues to what happens before, during, and after the advance of an active continental ice sheet, in contrast to a stagnating ice sheet such as that of the Illinoian glaciation.





## Dating the Wisconsin Glaciation

A unique feature of the Wisconsin glaciation in Illinois in comparison with earlier ice advances is that it took place during the time for which carbon-14 dating can be used. This type of radiometric dating can reliably determine the age of organic matter (biologically derived materials containing carbon) as old as 50,000 years. Thus, not only can we date the beds of till, sand and gravel, and lake silts and clays in relation to each other using the law of superposition, but where organic matter occurs within these sediments, we can also sometimes bracket the actual time that the sediments were deposited.

For example, wood found in a zone of organic silt at the base of Wisconsin Episode deposits in northeastern Illinois has been dated to approximately 25,000 years before present. This tells us that ice began to advance into the state at approximately that time, because the organic silt underlies till deposited by the Wisconsin Episode ice. At the farthest southward advance of that ice, near Shelbyville, wood has been found that dates to about 20,000 years before present. We know, then, that it took approximately 5,000 years for that glacier to reach its maximum extent. In abandoned beaches of Lake Michigan, where the lake level stood at higher elevations while the ice front was retreating into the lake basin, wood has been found that dates from 14,000 to 13,000 years ago. Thus, in Illinois, the deposits of the Wisconsin Episode that contain wood and other organic material are anchored in time, and we know that the glacier deposited its load of rock debris in Illinois over a period of about 12,000 years (between 25,000 and 13,000 years ago).

### THE TIME-TRANSGRESSIVE NATURE OF GLACIAL DEPOSITS

Table 2 illustrates a very important idea for understanding times of glaciation and ice withdrawal. This idea, called time-transgression, means that a layer of sediment with distinctive characteristics was deposited in an environment that shifted geographically with advancing time, and its age consequently varies from place to place within the area where it was deposited.

As an example of this concept, consider the area of the last glaciation. As explained in the text on this page, we know that the Wisconsin glaciation began earlier in Canada than it did in Illinois, and we also know that it ended in Illinois before it did in Canada. As we know from radiometric age-dating, the ice began advancing into northeastern Illinois about 25,000 years ago, reached its southernmost extent near Shelbyville about 20,000 years ago, and then finally melted back into the Lake Michigan basin between about 14,000 and 13,000 years ago. Therefore, the earliest Wisconsin Episode till was deposited in the Chicago area some 5,000 years earlier than at Shelbyville. Near Shelbyville, till was deposited over about a 2,000-year span, whereas at Chicago, tills may have been deposited over about a 12,000-year span. Wisconsin Episode till was deposited about 5,000 or 6,000 years later in the Chicago area than it was at Shelbyville. For these reasons, deposits such as the tills of the last glaciation are said to be time-transgressive.

— Myrna M. Killey

### What We Learn from Wisconsin Episode Sediments

In exposures of these deposits from the most recent ice advance, we can see not only the sediments themselves but also find clues to how they were deposited. Till that is dense, massive, and overconsolidated was deposited directly at the base of the ice and compacted by the weight of the glacier moving over it. Till-like sediments that are not massive and overconsolidated may have flowed off

the ice as a muddy mass. Layered (bedded), fine grained sediments were probably deposited in a lake bed; thin layers (rhythmites) of clay, silt, and sand indicate cyclic deposition, for example, in annual cycles. And vertically graded and sorted sediments indicate sediments were carried and deposited by running water of different speeds, or velocities. For example, a sequence of layers that goes from coarse sand and gravel to fine sand indicates the sediments were carried by water that gradually slowed down. Faster moving water can carry coarser as well as fine grained material. As the water slows, it can no longer carry the coarser grains, and they settle out first.

Because the sediments from older glaciations may have been weathered or partially eroded, overridden, and compacted by younger ice sheets, many of these depositional clues are missing, buried, or distorted. Therefore, the evidence for determining how they were deposited is often much less clear, as well as less accessible, than that of more recent or modern glaciers. Nevertheless, the processes responsible for the compaction, layering, and sorting we see in sediments exposed at the ground surface today were likely the same for the older, more deeply buried sediments from earlier glaciations.

### ICE AGE DUST CLOUDS OVER ILLINOIS

For tens of thousands of years as glaciers crept into the Great Lakes and into the headwaters of the Mississippi and Missouri Rivers, those rivers carried vast quantities of meltwater and sediment to the Gulf of Mexico. Melted at their base by the heat of the earth and at their surface by the sun, the glaciers issued forth first trickles, then torrents that carved and flooded the river valleys to the south. At times the meltwater floods reached from bluff to bluff across the valleys; but when floodwaters receded, they left barren, sediment-covered islands and temporarily empty stream channels exposed to winds. These sediment surfaces dried quickly.

In the brisk, dry, winter winds, sand grains began to move, accumulating first in ripples and then in small migrating dunes that moved across the land surface. The sand grains in turn kicked up smaller silt- and clay-sized grains that rose into the turbulent air and were suspended and carried downwind in dust clouds. The clouds moved the suspended silt far downwind, much like the dust clouds that occasionally rise from freshly plowed spring fields today. As the dust clouds, moved by winds that usually blew from the northwest, traveled away from their source in the big river valleys, the largest particles fell first as clouds dispersed and winds dissipated. The finest particles were carried tens of miles.

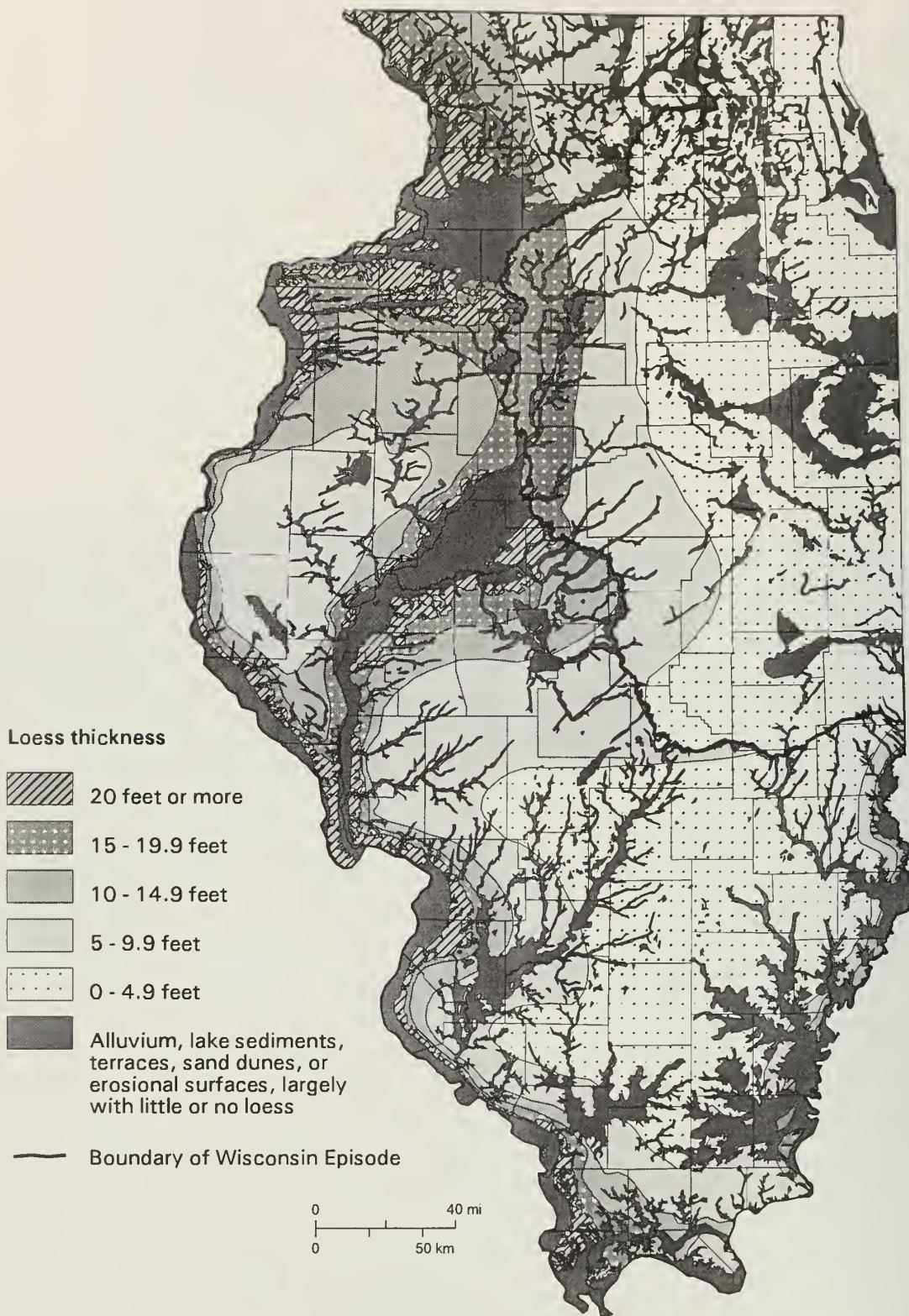
As the dust cloud passed, the silt settled to the ground. Trees and grasses slowed the wind near the ground and trapped the dust. Most of the time, the dust accumulation was almost imperceptible, but gradually deposits thickened. On average, less than 1/25 inch fell each year in the areas of fastest deposition, those areas closest to the valleys. Elsewhere, the dust fell even more slowly. It took almost 1,000 years for about 3 feet of dust to accumulate. Not only did the dust accumulate slowly, it probably accumulated at variable rates. Some of the dust storms may have been heavy and dark and may have lasted for weeks. But mostly the dust fell gradually.

Near the Mississippi and Illinois River valleys, this wind-blown dust, called loess by geologists, is over 100 feet thick in places (fig. 25). Farther from these valleys, the loess is thinner. Much of southern Illinois is covered by at least 5 feet; western Illinois has more, about 10 feet on average. It is thinnest in northeastern Illinois where the glaciers stood while the loess accumulated elsewhere.

Eventually the climate warmed, the glaciers retreated, and dust deposition ceased. The upper part of the loess now began to be weathered into the silty topsoil and subsoil that form the fertile fields of Illinois. Illinois owes the richness of its soils to these ancient dust storms.

— E. Donald McKay





**Figure 25** This map shows that Illinois' loess blanket becomes thinner east of the major river valleys in the state.



## How Wisconsin Episode Glaciers Altered Major River Systems

During the Wisconsin Episode advance, the Mississippi River was permanently diverted westward to occupy the valley of the Ancient Iowa River along the west side of what is now Illinois, a course it still follows (fig. 23, no. 2). Its former valley from Fulton to the big bend, known as the Princeton Bedrock Valley, was buried by drift, including a great thickness of outwash sand and gravel. The great torrents of glacial meltwater flowing

LIBRARY

APR 01 1999

ILLINOIS STATE UNIVERSITY

### WHAT THE LOESSES OF ILLINOIS TELL US ABOUT THE ICE AGE

At the time of the Ice Age, there were probably no humans in North America to witness the flooding and dust clouds responsible for Illinois' blanket of loess. But the dust that fell recorded what happened.

In its mineral composition, loess records the changing composition of the debris carried by its source valleys. The most dramatic change in mineral composition records a time about 20,500 years ago when the glaciers flowing from Lake Michigan reached the Illinois River near Peoria, blocked the river, and diverted the ancient channel of the Mississippi River to its present channel along the west side of the state (fig. 23, no. 2). Huge floods, probably from temporary lakes held back in the glacier-dammed river valley, broke loose and filled the valleys to the south deeper than they have ever been filled in historic times. The fine sediment in the valleys was picked up and carried along with the wind. When it fell from the passing dust clouds, the dust gradually buried and preserved snails, wood, pine and spruce needles, and traces of grasses. These fossils are found today. In the dust deposits are also found the burrows of ground squirrels and crayfish and the traces of roots and burrowing worms and insects. During periods of slow accumulation, the dust was altered by weathering.

The record of loess accumulation during the last glaciation in Illinois tells us that from about 50,000 to about 12,500 years ago, our big rivers were carrying glacial meltwater. The earliest meltwater carried debris that was reddish due to the red sediment entering the headwaters of the Mississippi River from the Lake Superior area. This sediment, when picked up and redeposited by the wind, became the reddish brown loess deposited between about 50,000 and 28,000 years ago that is called the Roxana Silt.

Between about 28,000 and about 25,000 years ago, the glaciers retreated into the Great Lakes basin, loess accumulation slowed, and weathering and soil-forming processes kept up with the accumulation for a while. A distinct weathered zone from that time (the Farmdale Soil, table 2) is found in the loess near the source valleys. But about 25,000 years ago, the glaciers readvanced and emerged from the southern end of Lake Michigan. The renewed pulse of meltwater carried yellowish brown and gray debris, and the new loess, the Peoria Silt, was yellowish brown in color. Similar loess was deposited along the Illinois, Wabash, Ohio, Mississippi, and Missouri valleys. About 12,500 years ago, loess deposition ceased along the Mississippi valley. Today, the Peoria Silt can be traced from Minnesota to Louisiana and from Nebraska to Ohio.

Loess deposits from several earlier glacial episodes are also present in deposits along the big rivers of Illinois. In places near the river valleys, loess can be seen in deep stream valleys or quarries that have cut through younger sediments. Near Collinsville in southwestern Illinois, three older loesses offer silent witness of earlier cycles of the Ice Age during which glaciers sent forth ice tongues and spewed meltwater torrents, and winds blew dust clouds across the land. The weathering of soils in the upper surfaces of the buried loesses tells of warm periods like today that intervened only to be followed by another frigid glacial episode that buried the soils with more loess or debris from the advancing ice.

Study of the loess deposits of Illinois offers insights into past climate changes, the advance and retreat of glaciers, the composition and formation of soils, the effect of erosion on the stability of ancient landscapes, and the plant and animal life that inhabited the past landscapes of Illinois.

—E. Donald McKay

away from the ice contributed to the widening and deepening of the Mississippi River valley.

## **Distinguishing Wisconsin Episode Deposits from Older Illinois Episode Deposits**

As with the earlier glaciations, it is the layers of tills deposited during the Wisconsin Episode glaciation that can be most easily traced and correlated across long distances. Wisconsin Episode tills can be distinguished because they occur above the easily recognized Sangamon Soil or the Robein silt marker bed mentioned on page 46, because they are exposed in many roadcuts, stream banks, and quarries and have distinctive grain sizes and mineralogical compositions. Three bundles of tills have been distinguished. The oldest of these generally exhibits a unique pinkish brown color and is fairly sandy, the next till lying above it is gray and siltier, and the uppermost till is also gray but very clayey and is the result of the ice gouging out shale and lacustrine sediments in the Lake Michigan basin area.

Like the tills left by earlier glaciers, those of the Wisconsin glaciation contain some sand and gravel beds that serve as aquifers, supplying water for many individual households, farms, and small communities throughout the northeastern quadrant of the state.

## **LANDSCAPES OF THE ILLINOIAN AND WISCONSIN GLACIATIONS**

If you look carefully at both the topography of the Illinoian till plain and the topography of the landscape in northeastern Illinois, where the younger Wisconsin Episode deposits underlie the loess, you will see some striking differences (fig. 26). For one thing, you can see evidence of a longer period of erosion and dissection of the land surface (for example, well developed drainage pat-

**Figure 26** This computer-generated shaded relief map shows the landforms of Illinois as if seen from a satellite and as if the sun were shining from the northwest at about 30° above the horizon. With this map one can visualize the natural patterns and shapes of higher and lower ground in Illinois.

Areas of complex patterns of dark and light represent rugged areas of contrasting relief. The light areas represent the northwest sides of steep slopes, and the darkest areas represent shaded southeast slopes. Broad areas of gray represent flat land. Recognizable are five main areas of the Illinois landscape.

1. The very flat floodplains of the Mississippi, Illinois, Wabash, and Ohio Rivers are represented by large gray areas of little to no contrast between light and dark. The higher elevations between the river valleys are referred to as upland areas.

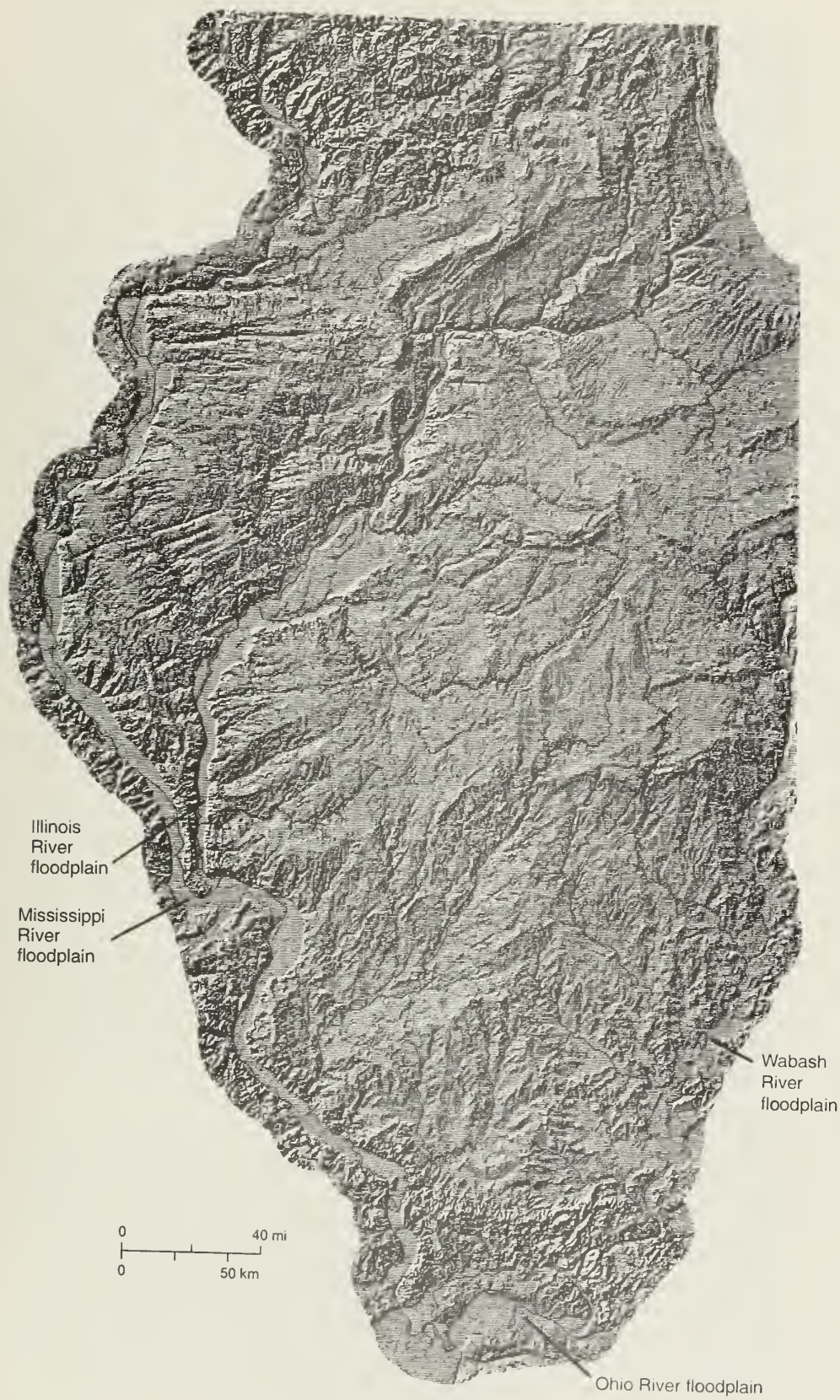
2. The most complex patterns of light and dark appear in the rugged unglaciated areas of northwestern Illinois, southern Illinois, and the narrow peninsula of land between the Mississippi and Illinois Rivers; these hilly areas have been subject to erosion since well before the Ice Age. Patterns of light and dark near the major river valleys represent areas where streams in small valleys flowing into main river valleys have dissected the landscape.

3. Across much of the southern third of the state, north of the rugged unglaciated hills, are tree-like branching drainage patterns. These dendritic patterns developed by erosion after the melting of the Illinoian glaciers about 125,000 years ago.

4. The northeast quadrant of the state is broader and flatter than elsewhere, except for the major river floodplains. Visible in this quadrant are the curved moraines with interspersed flatter areas and less well-developed stream valleys.

5. In western Illinois between the Mississippi and Illinois Rivers is a striking parallel pattern of east-northeast to west-southwest drainage. This pattern may be related to the crevasse patterns that developed on the wasting Illinoian ice. The valleys may later have been deepened by meltwater running off the Wisconsin glacier as it stood at its maximum extent.







terns) on the Illinoian till plain because this land surface has been exposed to these processes for a much longer period of time. For another, the flat Illinoian till plain contrasts with the end moraines, formed of till, that arc across northeastern Illinois (fig. 26) and record the pulsations, or short-interval advances and retreats, of the Wisconsin Episode ice front. This pattern of curved moraines distinguishes the Wisconsin Episode landscape from other landscapes of the state. It is easy to imagine the curved outer ends, or edges, of the ice lobes where the ground-up rock debris was carried to these ridges.

Wisconsin Episode end moraines may stand 50 to 100 or more feet above the flatter, slightly undulating surface of the *ground moraine* between them (fig. 10). The end moraines may be a few to several tens of miles long and from one-half to several miles wide (fig. 24). Glacial lake plains are usually several miles in length and width. Kames and kettles may be several tens to a hundred feet across. Kames rise a few tens of feet above the surrounding landscape and may be somewhat isolated on ground moraines, whereas kettles are depressions of somewhat lesser depth below the surrounding landscape and may often be found as part of the knob-and-kettle topography of some end moraines.

### **Sediments Other than Tills**

Like the deposits of the earliest glaciations, those of the Illinoian and Wisconsin glaciations contain numerous *lenses* and beds of sand and gravel, as well as silts and clays. The sand and gravel beds may serve as aquifers for municipalities, industry, and farms and households. In some areas, extensive beds of sand and gravel, probably deposited by meltwater in front of the advancing glacier, underlie the Illinoian and Wisconsin Episode deposits. These deposits serve as major water sources for some communities.

### **AFTER THE WISCONSIN GLACIATION**

As the climate again warmed, the Wisconsin Episode ice retreated from Illinois for the last time, about 14,000 to 13,000 years ago, although it remained active for a short time north of Illinois. Modern soil began forming across the landscape, and other geologic processes such as erosion and deposition by wind and water continued. As the ice melted back into the Lake Michigan basin, meltwater periodically ponded between the ice front and the moraines bordering the lake; several successively lower lake stages formed before the level of modern-day Lake Michigan was reached. As the ice continued to recede northward, Lake Michigan and the other Great Lakes gradually began to assume their present configuration.

### **Kankakee and Fox River Floods**

As the Wisconsin Episode glacier stood building the broad belt of moraines that rim the southern end of Lake Michigan, its meltwaters flooded into the Kankakee and Fox River valleys (fig. 23, no. 3), which could not contain such large volumes of water. The torrent of meltwater pouring down the valleys was so great that it ripped up and carried slabs of bedrock along with it. It also scoured some of the glacial deposits laid down by previous glaciers. Long bars of rubble accumulated along the flood's course; this rubble remains today as evidence of this major flood. Rubble and slabs of bedrock below the ground surface in the valley indicate that this was but the last of a series of floods that began earlier in the Wisconsin Episode.

## **Glacial Lake Sediments**

Glacial meltwater continued to pond between moraines and the ice front, even after the ice had retreated well back into the Lake Michigan basin. Lake sediments were deposited across what is now the greater Chicago-land area, and the existence of beaches, bars, and spits attests to former lake shores. The higher ground now occupied by the village of Blue Island actually was an island in a lake. The city of Chicago is built on a glacial lake plain.

In the southeastern part of the state, so much outwash was deposited by meltwater coming down the Wabash River that the valley could not contain it all. Water backed up into the valley's tributaries, creating lakes in which up to 20 feet or more of silt and clay accumulated.

## **Sand Dunes**

Broad areas of outwash provided material that was picked up by the wind and redeposited, resulting in tracts of sand dunes along the middle Illinois River valley, along the Mississippi River valley (especially in Rock Island, Mercer, and Henderson Counties), in the Green River and Havana Lowlands, and along the Kankakee River valley in the eastern parts of Kankakee and Iroquois Counties. We know this process took place shortly after the deposition of the outwash and waning of the meltwater floods because most of the dunes are now anchored in place by vegetation.

### **BASIC RESEARCH LEADS TO GOOD GEOLOGIC MAPPING . . .**

Detailed geologic maps provide a technical basis for managing and using land and groundwater resources and for evaluating mineral resource potential. The first step that must be taken when constructing a detailed geologic map is conducting basic geologic research. This research involves identifying the earth materials present in a region, including the form and areal extent that they take on the land surface, the degree to which they are present in the subsurface, and their thickness and character. It also includes investigating how the deposits got there, which in turn aids in understanding how they may change from one place to another. Once geologists have a fundamental understanding of the geologic materials, they can make maps showing the horizontal distribution of these deposits across an area.

### **. . . GEOLOGIC MAPPING LEADS TO PREDICTABILITY . . .**

Geologists also want to understand the vertical sequences of deposits across the mapped area. In order to do this, they draw cross sections (hypothetical vertical slices from the ground surface downward to some chosen depth; see fig. 18) that show the continuity of glacial deposits between points of observation—stream banks, roadcuts, and wells. Cross sections also present information on the thickness of the deposits and the elevation of the tops of major buried surfaces or specific materials. They can also indicate where a particular deposit begins to thin and, if sufficient information is available, can generally predict where it may no longer exist. Even though specific information at a particular point may not exist, the completed cross section can be used to predict what might be found below the earth's surface at this point. The only way to find out the actual kinds and thicknesses of deposits at any one point is to drill there and see if observations actually match predictions.

### **. . . AND PREDICTABILITY IS IMPORTANT FOR APPLICATIONS**

Good geologic maps and cross sections based on adequate and accurate data provide a sound scientific basis for making critical decisions on such applied geologic problems as finding and appropriately utilizing scarce mineral resources, locating and protecting water supplies, siting waste-disposal facilities, treating indoor radon, cleaning up contaminated industrial and other sites, and improving land-use planning in general. But large-scale, detailed geologic maps do not exist for large areas of Illinois. Some geologic maps are out-of-date and do not incorporate the latest geologic information. Up-to-date, detailed geologic maps pay off when (1) determining the kinds of resources Illinois has, whether they are economically recoverable, and how long they will last, and (2) deciding the best ways to use and protect the land for present and future generations, and for such important activities as cleaning up contaminated sites and siting new facilities in places that will minimize the potential for contamination.

—Richard C. Berg



## EPILOGUE: ARE WE STILL IN THE GREAT ICE AGE?

---

Researchers who study modern climate change are delving deeply into evidence from the Ice Age to answer the above question. Cores of ocean sediments and of relatively undisturbed ice from Greenland and Antarctica are being studied intensively to determine the mechanisms responsible for rapid climate shifts during the Great Ice Age. There are no definite answers to this question. As we have seen, during the Ice Age, Illinois went through repeated alternations between cold glacial climates and warm interglacial climates, the latter often warmer than today's climate. Research into the causes of Ice Age climatic change may also shed light on human influences on climate.

Much research must yet be done in order to answer all the questions remaining about past glaciations in Illinois. Understanding more about these glaciations and the reasons behind their occurrence will aid in answering the question of whether or not we are still living in the Ice Age.

Continuing study of Ice Age deposits allows scientists to constantly add to the store of knowledge about the nature and extent of these deposits. As our understanding about Ice Age deposits and the processes that are responsible for them grows, we can map them more accurately, heighten public awareness of potential geologic hazards, and use the land and its mineral and water resources more intelligently for both ourselves and future generations.

## FOR FURTHER READING

- Abert, Curtis C., 1996, Shaded Relief Map of Illinois: Illinois State Geological Survey Illinois Map 6.
- Bates, Robert L., and Julia Jackson, 1980, Glossary of Geology, 2nd edition: American Geological Institute, Falls Church, VA, 749 p.
- Bauer, Robert A., Billy A. Trent, and Paul B. DuMontelle, 1993, Mine Subsidence in Illinois—Facts for Homeowners: Illinois State Geological Survey Environmental Geology 144, 16 p.
- Bergstrom, Robert E., ed., 1968, The Quaternary of Illinois—A Symposium in Observance of the Centennial of the University of Illinois: University of Illinois College of Agriculture Special Publication No. 14, 179 p.
- Chrzastowski, M. J., 1991, The building, deterioration and proposed rebuilding of the Chicago lakefront: Shore & Beach, vol. 59, no. 2, p. 2–10.
- Chrzastowski, M. J., M. M. Killey, R. A. Bauer, P. B. DuMontelle, A. L. Erdmann, B. L. Herzog, J. M. Masters, and L. R. Smith, 1994, The Great Flood of 1993—Geologic Perspectives on the Flooding along the Mississippi River and Its Tributaries in Illinois: Illinois State Geological Survey Special Report No. 2, 45 p.
- Earthquakes in Indiana: Indiana Geological Survey and Indiana State Emergency Management Agency, Indianapolis, IN, brochure, 6 p.
- Embleton, C., and C. A. M. King, 1975, Glacial and Periglacial Geomorphology, 2nd edition: Edward Arnold, London, 2 vols.
- Eyles, N., ed., 1983, Glacial Geology: Pergamon Press, New York, 489 p.
- Flint, Richard Foster, 1971, Glacial and Quaternary Geology: John Wiley and Sons, Inc., New York, 892 p.
- Goldthwait, R.P., ed., 1975, Glacial Deposits: Dowden, Hutchinson, and Ross, Stroudsburg, PA, 464 p.
- Guide to the Geologic Map of Illinois, 1961, Illinois State Geological Survey Educational Series 7, 24 p.
- Hall, Dorothy K., 1986, Get close to glaciers with satellite imagery: The Science Teacher, November 1986, p. 23–38.
- Hall, Dorothy K., 1989, Global climate change—Notes from the field—Uplinks provide updates: The Science Teacher, September 1989, p. 66–70.
- Hallberg, George R., Thomas E. Fenton, Timothy J. Kemmis, Gerald A. Miller, 1980, Yarmouth Revisited: Iowa Geological Survey Guidebook, 27th Field Conference, Midwest Friends of the Pleistocene, Iowa Geological Survey, Iowa City, IA, 130 p.

- Hansel, Ardith K., and W. Hilton Johnson, 1996, Wedron and Mason Groups, Lithostatigraphic Reclassification of Deposits of the Wisconsin Episode, Lake Michigan Lobe Area: Illinois State Geological Survey Bulletin 104, 116 p.
- Harbaugh, John W., 1968, Stratigraphy and Geologic Time: W. C. Brown Company, Dubuque, IA, 113 p.
- Horberg, Leland, 1950, Bedrock Topography of Illinois: Illinois State Geological Survey Bulletin 73, 111 p.
- Horberg, Leland, 1953, Pleistocene Deposits below the Wisconsin Drift in Northeastern Illinois: Illinois State Geological Survey Report of Investigations 165, 61 p.
- Horberg, Leland, 1956, Pleistocene Deposits along the Mississippi Valley in Central-Western Illinois: Illinois State Geological Survey Report of Investigations 192, 39 p.
- Ice Age Geology—Illinois and Michigan Canal National Heritage Corridor, 1988, National Park Service, U.S. Department of the Interior, brochure.
- Imbrie, John, and Katherine Palmer Imbrie, 1979, Ice Ages—Solving the Mystery: Harvard University Press, Cambridge, MA, 224 p.
- John, B. S., 1977, The Ice Age, Past and Present: Collins, London, 254 p.
- Johnson, W. H., 1976, Quaternary stratigraphy in Illinois—Status and current problems, *in* Quaternary Stratigraphy of North America, W. C. Mahaney, ed., Dowden, Hutchinson, and Ross, Stroudsburg, PA, p. 161–196. (ISGS Reprint 1977-K)
- Killey, M. M., J. K. Hines, and P. B. DuMontelle, 1985, Landslide Inventory of Illinois: Illinois State Geological Survey Circular 534, 27 p.
- Kim, S. M., R. R. Ruch, and J. P. Kempton, 1969, Radiocarbon Dating at the Illinois State Geological Survey: Illinois State Geological Survey Environmental Geology Note 28, 19 p.
- Masters, John M., 1978, Sand and Gravel and Peat Resources in Northeastern Illinois: Illinois State Geological Survey Circular 503, 11 p.
- Meents, Wayne F., 1960, Glacial-Drift Gas in Illinois: Illinois State Geological Survey Circular 292, 58 p.
- Meier, M., and A. Post, 1988, Glaciers—A Water Resource: U.S. Geological Survey, Washington DC, 23 p.
- Mueller, Pietra, 1994, Viewing an ancient world from a frozen lake, *in* The Living Museum, Illinois State Museum, Springfield, IL, vol. 56, no. 1, p. 3–5.
- Nuhfer, Edward B., Richard J. Proctor, and Paul H. Moser, 1993, Citizens' Guide to Geologic Hazards: American Institute of Professional Geologists, Arvada, CO, 134 p.
- Palmer, A. R., 1983, The decade of American geology—1983 geologic time scale: *Geology*, vol. 11, p. 503–504.
- Pielou, E. C., 1991, After the Ice Age: University of Chicago Press, Chicago, IL, 366 p.



- Prior, Jean C., 1991, *Landforms of Iowa*: University of Iowa Press, Iowa City, IA, 153 p.
- Ray, Louis L., 1992, *The Great Ice Age*: U.S. Government Printing Office 1992-307-568, 15 p.
- Schuberth, Christopher J., 1986, *A View of the Past—An Introduction to Illinois Geology*: Illinois State Museum, Springfield, IL, 181 p.
- Sharp, R. P., 1988, *Living Ice—Understanding Glaciers and Glaciation*: Cambridge University Press, New York, 225 p.
- Short, Nicholas M., and Robert W. Blair, Jr., eds., 1986, *Glaciers and glacial landforms*, in *Geomorphology from Space—A Global Overview of Regional Landforms: Scientific and Technical Information Branch*, National Aeronautics and Space Administration, SP-486, p. 521–596.
- Thelin, Gail P., and Richard J. Pike, 1991, *Landforms of the Conterminous United States—A Digital Shaded-Relief Portrayal*: U.S. Geological Survey. 16 p. plus map, I-2206.
- U.S. Environmental Protection Agency, 1990, *The greenhouse effect—What can we do about it?*: EPA Journal, vol. 16, no. 2, 60 p.
- Williams, Richard S., Jr., 1983, *Glaciers—Clues to Future Climate?*: U.S. Geological Survey, U.S. Government Printing Office 1983-381-618/102, 21 p.
- Williams, S. Jeffress, Kurt Dodd, and Kathleen Krafft Gohn, 1990, *Coasts in Crisis*: U.S. Geological Survey Circular 1075, 32 p.
- Willman, H. B., and John C. Frye, 1970, *Pleistocene Stratigraphy of Illinois*: Illinois State Geological Survey Bulletin 94, 204 p.
- Willman, H. B., H. D. Glass, and John C. Frye, 1963, *Mineralogy of Glacial Tills and Their Weathering Profiles in Illinois. Part I. Glacial Tills*: Illinois State Geological Survey Circular 347, 55 p.
- Woods Hole Oceanographic Institution, 1989, *The Oceans and Global Warming*: *Oceanus* 32 (Summer), 96 p.

## GLOSSARY

The definitions below are based in part on the Glossary of Geology, second edition, published by the American Geological Institute.

**ablation** The processes by which snow or ice is lost from a glacier, including melting, evaporation (sublimation), and wind erosion. Verb: ablate.

**accretion-gley** *See* gley.

**alluvium** Sediment eroded from adjacent areas and deposited by running water in and along rivers and streams.

**aquifer** A saturated sediment or rock that is sufficiently porous and permeable to be useful as a source of water and that provides a generally sustainable yield of suitable quantities of ground water.

**areal** (as in areal distribution) Refers to the geographic area over which a rock or sediment unit occurs, either buried or exposed at the surface.

**bed** A layer of sediment or sedimentary rock; *see* **strata**.

**bedrock** The solid rock that underlies **unlithified** sediment of glacial and other origins.

**correlate** To show a definite correspondence in character and stratigraphic position between geologic **formations** in two or more separated areas.

**crevasse** A deep, nearly vertical crack in a glacier or ice mass caused by stresses resulting when the ice moves over an uneven surface.

**crop out** A verb related to the noun **outcrop**.

**cross section** A diagram or drawing that shows the sequence of rocks and sediment layers as they occur in a vertical plane; commonly drawn from the ground surface down to some selected depth, such as the bedrock surface.

**cuesta** A ridge with a gentle slope on one side and a steep slope on the other.

**diamicton** A general term for unsorted, unstratified rock debris composed of a wide range of particle sizes; use of this term carries no suggestion about how such debris was formed or deposited (see sidebar on p. 11).

**dolomite** A sedimentary rock (calcium magnesium carbonate) similar to limestone (calcium carbonate) and especially common in the bedrock of northeastern Illinois.

**drift** *See* glacial drift.

- embayment** A deep indentation or recess of a shoreline that forms a bay.
- end moraine** A ridge formed by the accumulation of glacial drift at the edge of a glacier. In Illinois, most end moraines are composed predominantly of till.
- erratics** Boulders and other rock fragments transported by glacial ice from their place of origin to an area where the bedrock is different.
- esker** A long, narrow, sinuous ridge of sand and gravel deposited by a meltwater stream flowing upon, within, or beneath a glacier that is melting away.
- fabric** The preferred orientation of elongate pebbles and cobbles within a till. Fabric indicates the direction of ice movement.
- formation** The basic unit of **lithostratigraphic** classification. A formation must be identifiable on the basis of easily recognized physical properties and widespread enough to be mapped at a regional scale. A formation can be divided into smaller units (called **members**) where these, too, are recognizable and mappable. Formations can also be combined into **groups** when useful and appropriate.
- geologic map** A diagram or drawing on a horizontal plane of part of the earth's surface showing by means of lines, colors, symbols, and orientation the distribution of selected features such as particular surface or subsurface units of rocks or sediments.
- glacial drift** A general term for all rock material transported by a glacier and deposited directly by or from the ice, or by running water coming off a glacier.
- glacial lake plain** A large flat area underlain by fine grained sediment that was deposited in a lake formed by ponded meltwater from a glacier.
- glacial striations** A series of long, generally straight and parallel scratches or furrows on a bedrock surface which were caused by the dragging and scraping of rock fragments that were frozen into the base of an overriding glacier; striations are usually oriented in the direction of ice movement. Glacial striations are also formed on **erratics** (rock fragments) transported by the ice.
- glee or accretion-gee** Sediment that has accumulated (accreted) slowly in low, wet, poorly drained areas of the landscape; gee is often dark gray to black, massive, and dense.
- ground moraine** A gently rolling ground surface underlain by **till** deposited beneath a glacier. It is usually bordered by **end moraines**.
- group** The major **lithostratigraphic** unit next higher in rank than a **formation**; a group consists of two or more associated and adjoining formations having significant **lithologic** features in common.
- ice-wedge cast** A vertical wedge of sediment (or cast) that filled a crack in frozen ground formerly filled by an ice wedge; the wedge of ice was water that had frozen in a narrow crack in **permafrost** that was produced by thermal contraction.
- igneous** One of the three basic categories into which rocks can be classified, of which the other two are **sedimentary** and **metamorphic**. Igneous rocks are formed by the cooling of molten rock, called magma.



- kame** A low, steep-sided hill or mound composed mainly of poorly sorted sand and gravel that was deposited by meltwater plunging into crevasses near the front of a glacier.
- kame terrace** A terrace-like ridge consisting of stratified sand and gravel deposited by a meltwater stream between a melting glacier or stagnant ice lobe and a higher valley wall or lateral moraine. The ridge is left standing after the disappearance of the ice.
- kettle** A shallow basin- or bowl-shaped depression on the landscape formed when a large block of ice became detached from the main glacier; the ice block was gradually buried by outwash from the retreating ice and left a depression in the outwash when it eventually melted.
- lacustrine** Formed or deposited in a lake.
- leaching** The dissolving and removal of soluble minerals by water from rain and snow that infiltrates downward through a soil.
- lens** A geologic deposit with surfaces that converge toward each other; a lens is thick in the middle and thins out toward the edges.
- lithified** Changed over time from a loose sediment into a coherent and solid rock by means of cementation, compaction, and compression.
- lithologic** The physical character of rocks or sediments, including mineralogical composition, grain size, color, and structure.
- lithostratigraphic** Pertaining to the classification of rock and sediment that is based solely on **lithologic** similarities within a unit and on lithologic differences between adjacent rock or sediment units. "Litho-" refers to the physical character of the rocks or sediment, and "stratigraphic" refers to the systematic arrangement of units of rock and sediment.
- lithostratigraphic unit** A stratigraphic unit defined and identified by **lithologic** features without regard to origin, fossil content, or time boundaries.
- loess** Windblown dust; a widespread, homogeneous, massive, unconsolidated but slightly coherent, fine grained deposit that blankets much of today's Illinois landscape. In Illinois, loess deposits range from about 100 feet thick on the east sides of major rivers to less than 5 feet over much of the eastern half of Illinois. See sidebar on p. 51.
- member** A **lithostratigraphic** unit of subordinate rank; a recognizable and mappable subdivision of a **formation**.
- metamorphic** One of the three basic categories into which rocks can be classified, of which the other two are **sedimentary** and **igneous**. Metamorphic rocks are those changed in composition, mineral content, texture, or structure by the application of heat or pressure; they originally may have been sedimentary, igneous, or other metamorphic rocks.
- organic** Biologically derived materials containing carbon as an essential component, usually bonded with hydrogen. Organic geologic materials include wood, shells, peat, and bone.
- outcrop** Part of a glacial deposit or bedrock that is exposed and visible at the earth's surface.

- outwash** Stratified sand and gravel that was washed out from a glacier by meltwater streams and deposited in front of, or beyond the margin of, an active glacier.
- overburden** Sediment or rock that overlies an economically useful deposit and which must be removed prior to mining that deposit.
- overconsolidated** Sediment that is more consolidated than would be expected from the existing overlying sediments. In the case of tills, overconsolidation resulted from compaction by the extremely heavy glacier overriding the sediment.
- patterned ground** Ground surface having polygonal or circular patterns that develop in poorly drained areas subject to intensive frost action; the patterns are defined by contrasting soils.
- permafrost** Soil or rock at or near ground surface in arctic or subarctic regions that has been continuously frozen for a long time.
- proglacial** Immediately in front of, or just beyond the outer edge of, a glacier; proglacial refers to lakes, streams, deposits, and other features produced by or derived from glacial ice.
- radiometric age-dating** A method for calculating the age for a specimen by measuring the amount of a radioactive element remaining in the specimen. The method is based on the known, fixed rates of nuclear decay of natural elements such as carbon-14, potassium-40, and certain other radioactive elements.
- relief** A term used loosely for the general unevenness of the earth's surface; more precisely, it refers to the vertical difference in elevation between hilltops and valleys of a given region. A region showing little variation in elevation has low relief.
- rhythmites** A repetitive succession of rock or sediment units in which the layers indicate a frequent and predictable pattern of the same sequence of conditions. No thickness or time (such as seasonal variations) is implied when this term is used.
- sedimentary** One of the three basic categories into which rocks can be classified, of which the other two are **igneous** and **metamorphic**. Sedimentary rocks are formed by the compaction and cementation of sediment or by the precipitation of dissolved minerals from salt or fresh water.
- seismic** Pertaining to a vibration in earth materials that may be artificially induced or due to an earthquake. Seismic methods used in investigating the subsurface include the generation, reflection, refraction, detection, and analysis of elastic waves in the earth.
- soil horizons** Zones of successively greater alteration that develop in a geologic material upon exposure to the physical and chemical processes of **weathering**.
- solifluction** The slow, viscous, downslope flow of waterlogged sediment and rock debris; solifluction especially occurs in regions underlain by frozen ground that acts as a downward barrier to water percolation.
- strata** Single and distinct layers, or beds, of sediment or sedimentary rock that are easily distinguishable from layers above and below them.

- stratigraphic, stratigraphy** Refers to the systematic definition and description of major and minor natural divisions of rocks and their arrangement according to their composition, distribution, correlation, and mutual relationships.
- stratigraphic code** A set of guidelines developed by a commission of geologists to aid in communication when referring to the layers of rock and sediment and to geologic history. Periodically updated and modified, the code contains guidelines to follow when classifying deposits and time.
- texture** The size, shape, and arrangement of the component particles of a sedimentary deposit such as a till.
- till** Unsorted, unstratified rock debris composed of a wide range of particle sizes that was deposited directly by and underneath a glacier.
- time-transgressive** A deposit that varies in age according to its geographic position; reflecting a depositional environment (for example, deposition by glacial ice) over a period of time during which the ice advanced and withdrew across a particular geographic area.
- topography** The general shape of a surface, such as the land surface, including its **relief** and the position of its natural and manmade features.
- truncate** To scrape off or plane off the top portion of a buried soil or other deposit by an advancing glacier.
- tundra** A treeless, level to undulating plain that is characteristic of arctic and subarctic regions. It usually has a marshy surface that supports a growth of mosses, lichens, and numerous low shrubs; it is underlain by a dark, mucky soil and **permafrost**.
- unlithified** Sediment that has not been changed into a coherent and solid rock.
- weathering** The process of physical disintegration and chemical decomposition whereby earth and rock materials are changed in color, texture, composition, firmness, or form upon exposure to the atmosphere.



## ACKNOWLEDGMENTS

---

I have borrowed freely from older publications, especially where I believe the phrases and wording used explained a concept well. Many authors of previous texts are here acknowledged for their contributions to the ideas and wording used in this booklet, and their publications are listed in "For Further Reading" at the end of the booklet. My purpose is to build on what they have done and to provide insights into the Ice Age events that occurred in Illinois.

Thanks and appreciation for encouragement, ideas, and helpful comments go to several colleagues. John P. Kempton of the Illinois State Geological Survey (ISGS) identified the need for such a booklet for the public many years ago and inspired its production through his continuing interest in and enthusiasm for the Quaternary in general and this publication in particular. Richard C. Anderson of Augustana College, Rock Island, Illinois provided careful reviews of the initial and revised manuscripts, gave strong and much appreciated encouragement, and supplied numerous photographs to illustrate certain features discussed in the text. Dean Timme of Parkland College, Champaign, Illinois, also fostered the production of this publication by noting the need for introductory textbook material for use by Illinois teachers. In addition, Ardith K. Hansel of the ISGS assisted with technical review, contributed several helpful photographs, helped revise and update the timetable of events and deposits of the Ice Age (table 2), reviewed the illustrations of kame, kettle, and esker formation, and provided insight into some future directions of glacial studies at the Survey. Leon R. Follmer of the ISGS also assisted with revision of table 2. W. Hilton Johnson of the University of Illinois assisted with review of the kame, kettle, and esker illustrations and contributed several helpful photographs. Pamela J. Cookus, ISGS, reviewed the manuscript from a lay person's point of view and contributed her creative word-processing skills. Kim Kuchenbrod also read an early portion of the manuscript. Particular thanks go to all sidebar authors—Richard C. Berg, Leon R. Follmer, Ardith K. Hansel, John P. Kempton, and E. Donald McKay, all of the ISGS—for their interest and willingness to contribute. Special appreciation goes to Thomas McGeary and Sandra Stecyk, ISGS, for their editing and artistic skills on this publication.



